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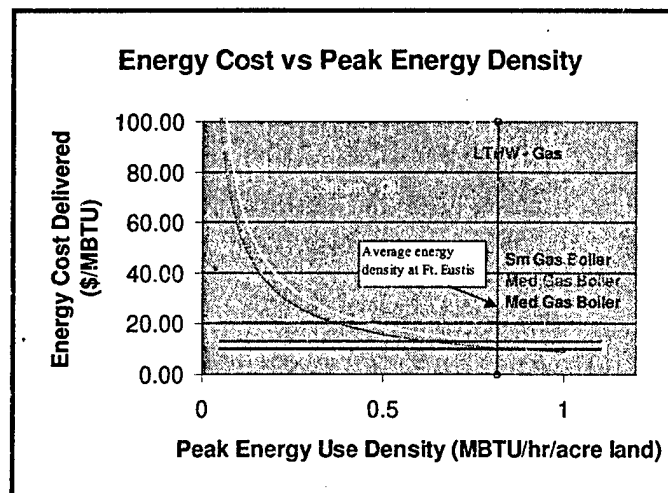
Engineer Research and  
Development Center

CERL Technical Report 99/96  
December 1999

# Central Heat Plant Modernization

## FY98 Update and Recommendations

Vicki L. Van Blaricum  
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Michael K. Brewer  
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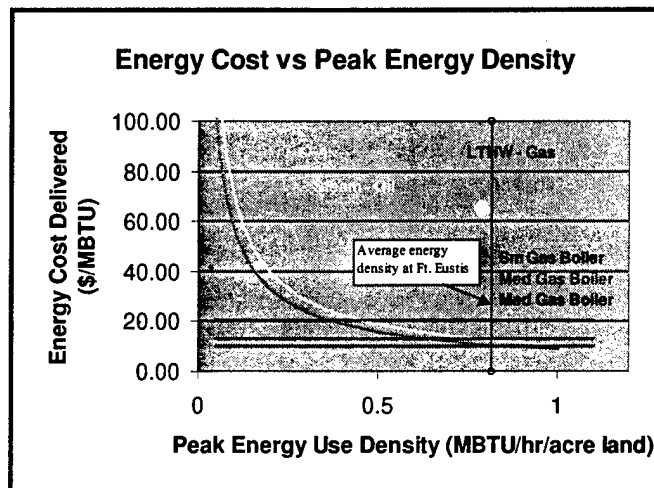
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## Foreword

This study was conducted for the Corps of Engineers Installation Support Center (CEISC) under Military Interdepartmental Purchase Request (MIPR) NCEGCE99710201, Work Unit VB8, "Central Energy Plant Modernization Support for FY98." The technical monitors were Dennis Vevang and John Lanzarone, CEISC-EM.

The work was performed by the Energy Branch (CF-E) and the Materials and Structures Branch (CF-M) of the Facilities Division (CF), U.S. Army Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was William T. Brown III. Larry Windingland is Chief, CEERD-CF-E; Dr. Ilker R. Adiguzel is Chief, CEERD-CF-M; and Dr. L. Michael Golish is Chief, CEERD-CF. The technical editor was William J. Wolfe, Information Technology Laboratory - CERL.

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# 1 Introduction

## Background

The Army has programmed \$60 million per year from fiscal year 1998 (FY98) through FY02 for the Central Heat Plant (CHP) Modernization Program. The purpose of the program is to modernize old and failing heating plant and distribution equipment so that the modernized plants and distribution systems will provide the installations with reliable, safe, energy efficient, and environmentally friendly service.

Projects are funded and executed under the CHP Modernization Program according to the following general procedure:

1. The installation performs an analysis of upgrade alternatives and decides on the best one.
2. The installation prepares a DD Form 1391 describing the proposed project and submits it to its Major Command (MACOM).
3. The MACOM reviews the proposal, and if it is acceptable, approves it and submits it to the Assistant Chief of Staff for Installation Management ACS(IM).
4. A survey team consisting of members of ACS(IM), the Corps of Engineers Installation Support Center (CEISC), the Army Audit Agency (AAA), the U.S. Army Construction Engineering Research Laboratory (CERL) and/or the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), the installation MACOM representative, and the local District visits the installation and validates the requirement and proposed project.
5. ACS(IM) approves the proposal and prioritizes it for funding.
6. The project is designed. This is funded by the installation and/or the MACOM. Installations are encouraged to use their local USACE district for design support.
7. Project funding is released from ACS(IM) to the MACOM. MACOM transmits the funding to the installation.
8. The project is constructed and commissioned.
9. Performance of the project is tested. Selected installations will be required to document the cost savings that have resulted from the project. Some installations will have their project savings verified by the AAA.



The work that is done by the installation Directorate of Public Works (DPW) during the first two steps is critical in determining whether or not the project will receive funding, and whether or not it will be deemed a success when it is completed. To obtain funding, the DPW must select the best modernization alternative and put together a proposal that will best meet the selection criteria of the MACOM and the ACS(IM). To be deemed a success, the project must be life-cycle cost effective. The calculation of payback and benefits must be able to stand up under the scrutiny of the AAA.

CERL previously published a data summary with guidance to help the DPW analyze modernization alternatives and prepare proposals (Durbin et al. 1998). This report augments that guidance with the FY98 events and findings.

## Objectives

The objectives of this study were to:

1. Provide an update on the overall CHP Modernization Program
2. Document the CHP Modernization survey team's FY98 site visits
3. Provide recommendations and resources to help installations that are currently planning or executing projects under the CHP Modernization Program.

## Approach

ACS(IM) and U.S. Army Center for Public Works (USACPW) representatives were interviewed about the status of the program and the plans for the upcoming years (Chapter 2).

Data collected during several of the FY98 CHP survey team's site visits were compiled and analyzed. The site surveys are discussed in Chapters 3 through 7. Several CERL-developed analytic tools were used at the sites to help select and/or validate energy supply options. These tools include:

- **HEATMAP:** This simulation program allows the engineer to run flow, pressure, and heat loss simulations for a steam, hot water, or chilled distribution system (Washington State Energy Office 1992). Simulations can be run for the existing system and for proposed modernization alternatives. HEATMAP also includes economic analysis capabilities. The only input needed for a HEATMAP simulation is an accurate map of the distribution system, along with basic data on the buildings served (area and building usage).

- **Energy screening tool:** This Microsoft Excel spreadsheet generates site-specific curves relating the cost of energy delivered to a building to the peak building energy density. Curves are generated for a variety of energy supply options based on *U.S. Department of Army Directorate of Public Works Annual Summary of Operations* (hereafter referred to as the "Redbook") data and/or data provided by the installation. This allows engineers to select the most economical energy supply option for various areas of the installation based on typical demand in that area.
- **Corrosion prediction models:** These models can predict external (soil-side) corrosion and internal (water-side) corrosion based on soil and water chemistry. The models can predict an approximate year of failure for a given pipe system.

Some general procedures, resources, and hints were assembled to help installations develop and analyze CHP modernization alternatives. Guidelines for preparing the DD Form 1391 were developed to help installations avoid common problems that occurred in the FY98 project approval process (Chapters 8 and 9).

## Mode of Technology Transfer

It is recommended that the results be used to update Army guidance documents, including Army Regulation (AR) 420-49, *Facilities Engineering, Utility Services* and Technical Manual (TM) 5-650, *Repairs and Utilities: Central Boiler Plants*.

## Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 yd	=	0.9144 m
1 sq ft	=	0.093 m <sup>2</sup>
1 cu in.	=	16.39 cm <sup>3</sup>
1 acre	=	4,047 m <sup>2</sup>
1 gal	=	3.78 L
1 lb	=	0.453 kg
1 psi	=	6.89 kPa
°F	=	(°C x 1.8) + 32

## 2 FY98 Program Update

### Status of Current Projects

#### *Fort Leonard Wood, MO*

This is a multi-phased project. Army Facilities Energy Program (AFEP) funds (\$2,500,000) are available for Phase I, which was scheduled to be awarded in FY98. Phase II is programmed to be funded at \$8,100,000 through the Army's Utility Modernization Program in FY00. This repair project will replace two failing central heating plants (Buildings 645 and 745) and the underground steam distribution system with natural gas-fired modular boilers in 80 individual buildings in the 600, 700, and 800 areas. The cost of the project includes 80 modular boilers and 22,704 ft of natural gas pipelines. The existing steam conversion equipment in the buildings will be removed and the underground distribution system will be abandoned in place, rather than trenched and removed. The natural gas system at Fort Leonard Wood is privatized. The installed natural gas pipelines will become part of the privatized system. The mechanical rooms are of sufficient size so as not to require any additional mechanical room construction. There is no associated construction cost for this project. This project was approved 8 September 1998.

#### *Fort Benning, GA*

The funded cost is \$10,000,000. This Maintenance and Repair (M&R) project will replace the deteriorated central heating plant and the deteriorated steam distribution system on the Main Post area by installing individual heating systems in 82 individual buildings. Repair of steam absorption chillers will be accomplished by replacement with simpler, modern electric chillers. Work includes installation of unit heaters, gas lines, gas meter/regulators, high efficiency low NOx hot water boilers, ground source heat pumps steam boilers with condensate receivers, pumps, insulation, piping and valves, fresh air louvers, construction of mechanical enclosures, electrical wiring, radio controlled (FM) controllers, energy monitoring and control system (EMCS) controllers, and related demolition (including asbestos removal) for heating system installation. Exterior work will include removal of steam pits, removal of fuel tanks, construction of a propane peak shaving plant (comprising 30,000-gal propane tanks and pumps), and

fencing. An associated construction project is planned to move the used oil facility by providing two 10,000-gal prefabricated concrete vaulted used oil tanks with pumps/piping/pad at central energy plant at Building 3250. These tanks will receive used oil post-wide for consumption by the heating plant at Building 3250. Three buildings also require additional mechanical room construction. They are Buildings 6, 398, and 1750. Total associated construction cost for this project is \$444,000. This project was approved 25 August 1998.

### ***Fort Jackson, SC***

This project has a funded cost of \$23,000,000. This M&R project will replace deteriorated high-temperature water (HTW) equipment and mechanical distribution systems in Central Energy Plant #2 (CEP #2) and in the areas and facilities serviced by the plant with a low-temperature water (LTW) system and associated equipment. This is a multi-phased project with a Programmed Amount (PA) of \$11,000,000 for Phase I, scheduled for FY98, and a PA of \$12,000,000 for Phase II, scheduled for FY99. Central Energy Plant #2 services six, 5-company Starship barracks/mess halls, the Moncrief Army Hospital, the 2200, 3200, and 4200 block areas, and mess halls. Phase I will replace five existing HTW boilers and distribution lines inside CEP #2 with five LTW boilers, controls, equipment, and distribution lines. The exterior work for Phase I will replace all direct burial HTW lines supplying the six Starship barracks with a concrete trenched, LTW system. Phase I will also repair mechanical systems inside each facility serviced by CEP #2 to a compatible LTW system, and replace HTW steam generators located in the Moncrief Army Hospital and in each of the active 4200 block and Starship barracks mess halls with gas-fired steam boilers. Phase II will replace HTW distribution lines with the LTW system in the 2200 block, 3200 block, 4200 block, and replace HTW distribution lines servicing the Moncrief Army Hospital, also with the LTW system. Phase II also includes removing failed boilers and chillers in Buildings 2100, 2435, and 2450 and connecting these facilities to the LTW distribution system. An economic analysis indicates that the most economical plan of action is to convert from HTW with direct buried lines to LTW in a concrete trench. This alternative has a payback of 3.9 years. Associated construction cost for this project is \$199,000 and provides an interconnection between CEP #1 and CEP #2. This project was approved 16 July 1998.

### ***Fort Lewis, WA***

The Funded Project Cost is \$6,400,000. This project repairs the failing heat source for 65 buildings in the 3000, 3600, 3700, and 3900 blocks; demolishes the failing high pressure steam boilers and associated piping within the central

heating building; abandons the failing steam distribution and condensate return piping in place; and provides individual heat sources in the buildings.

A second project (number 50968) replaces previously approved project number 49377, which was approved 2 June 1997, at a funded cost of \$10,600,000. Project 49377 provided for repair of the central steam plant; conversion to low temperature hot water (LTHW) with distribution in shallow trenches to 34 buildings; and replacement with natural gas infrared heaters, boilers/furnaces to 31 buildings. Boiler plant 14, Building 3850, is a central heating plant fueled by natural gas and fuel oil that provides steam for the 3000, 3600, 3700, and 3900 blocks of Fort Lewis. The boiler plant and heat distribution systems were constructed in 1957-58 and have not had any major alterations since construction. The underground piping is failing due to internal and external corrosion, and is covered with asbestos insulation that has become friable and has lost much of its insulating capability. Some buildings lack the required mechanical room space and will require small additions to provide space for boilers. In conjunction with this M&R project, \$430,000 will be spent to provide the additions to house the boilers. The Fort Lewis project was awarded 17 June 1998 at \$6,520,000.

#### ***Fort Drum, NY***

This project has a funded cost of \$16,000,000. This M&R project will repair a failing HTW system at Fort Drum, NY. The project provides gas-fired boilers and domestic hot water heaters for 84 buildings and deactivation of the existing HTW system. The project will be executed in two phases. Phase I, scheduled to begin in FY98, will include changing the fuel source for 62 buildings. Phase I will be about 70 percent of the total cost or about \$11,200,000. Phase II will include the remaining 22 buildings. Phase I of this project replaces the previously approved Utilities Modernization/FEMP portion of project number 48667, which was approved 2 June 1997. Final Phase II of the project is proposed to be funded as a FY99 Utilities Modernization project. Fort Drum has an existing natural gas infrastructure that supports approximately 2,250 units of family housing and over 100 administrative and commercial facilities. Consistent with Department of Defense (DoD) initiative, Fort Drum will privatize the entire natural gas infrastructure throughout the installation, to include the system expansion to accommodate this project. A third party heat plant produces HTW to the entire cantonment area. The government owns the HTW distribution system from near the third party heat plant to the 84 buildings.

The HTW distribution system, completed in 1988, is underground, has 136 manholes, and is 42 miles in length. However, the HTW distribution system has deteriorated since completion. Currently, it is characterized by flooded manholes,

sump pumps without reliable electric service, leaking valves, infiltration of groundwater into the heat distribution conduits, wet insulation around the heat distribution piping, and ineffective cathodic protection. Because of these problems, only 68 percent of the purchased HTW energy actually reaches the facilities. In addition, these problems are accelerating the corrosion of the heat distribution piping. CERL researchers have predicted a 5-year remaining life expectancy for the original remaining carrier pipe exposed to flooding, steaming, and ineffective cathodic protection.

The economic analysis favors the proposed natural gas conversion project over the HTW systems upgrade. In the economic analysis, the gas project was compared to two HTW approaches. The first approach, the status quo, incorporates the Utility Modernization shallow trench project along with continued operation and repair of the remaining HTW system, using direct burial construction. The second approach replaces the failing underground distribution systems with the modernized shallow trench construction. The net present value (NPV) of the gas conversion project is \$108 million, while the status quo has an NPV of \$191 million, and the shallow trench modernization has an NPV of \$180 million. There is no associated construction costs for this project number. Phase I of the Fort Drum project was awarded 30 August 1998 for \$8,600,000.

#### ***Aberdeen Proving Ground, MD***

This project consists of eight phases for the Army Research Laboratory (ARL), four phases for the Main Front, and the 4200 and 4100 Blocks. The contract has been awarded and delivery orders for seven phases out of eight for ARL have been awarded in February 1998. Start of these delivery orders were in March and August 1998 with completion ranging from December 1998 to December 1999. The total of these seven phases is \$2,436,000. For the Main Front, delivery orders for two phases out of four have been awarded in March 1998 with completion scheduled for calendar year 1998. The total of these two phases is \$840,000. For the 4200 and 4100 Blocks, three delivery orders have been awarded totaling \$1,296,000. Two delivery orders were awarded in February 1998 and one in May 1998. Construction for these delivery orders started in July and August 1998 with completion scheduled for December 1999.

#### **Planned CHP Modernization Program (FY99-02)**

Table 1 lists the planned projects during the remaining years of the program. Some installations have more than one project. Final project approval and

funding is contingent on the installation's ability to execute an economically favorable project and obligate the funding on the project in 1 fiscal year.

**Table 1. Planned CEP modernization projects, FY99-02.**

<b>FY99</b>	<b>FY00</b>	<b>FY01</b>	<b>FY02</b>	<b>Unfunded</b>
Jackson	Carson	Redstone	Gordon	Picatinny
Eustis	Aberdeen PG	Stewart	Rucker	Monmouth
Campbell	Redstone	Gordon	Lee	Bragg
Riley	Leonard Wood	Riley	Carlisle Barracks	Sill
Drum	Belvoir	McNair	Dix	Knox
Benning	Wainwright		Hood	Gillem
Wainwright			Myer	

### 3 Fort Eustis Analysis

#### Background Information

The base operations at Fort Eustis are government operated. The cantonment areas encompass approximately 440 acres of land and 18.6 million sq ft of buildings.

All of the heating plants are relatively small and unmanned. A utility monitoring control system (UMCS) by Johnson Controls is being installed in the boiler plants. All of the systems are dual fueled by #2 oil and natural gas. High pressure steam systems (40 to 100 psig) and low pressure steam (< 15 psig) systems are used to provide heating and domestic hot water (DHW) to the buildings.

The utility provider at Fort Eustis is Virginia Power, which becomes the prime contractor for buying natural gas and fuel oil. Natural gas is procured from the Defense Energy Supply Center (DESC). Four or five plants operate year-round, while the other plants operate during the winter season only. Virginia Power owns and maintains the meters, with one meter at the main gate. The architect/engineer (A/E) contractors for Virginia Power are: (1) Dewberry and Davis and (2) the Greenwood Partnership.

#### Site Survey: March 1998

CERL representatives visited Fort Eustis, VA, on 26 March 1998 to collect data and interview DPW energy personnel. The following sections summarize the information obtained during the visit.

##### *Heating Plant Survey*

In general, most of the plants and mechanical rooms were in fair to good condition. All of the plants will need some level of mechanical repair to realize the maximum benefit of improving the controls with a UMCS. When the plants are repaired, the equipment needs to be verified for compliance with the applicable gas piping and steam piping code. Most of the boilers would fall under American Society of Mechanical Engineers (ASME) boiler code CSD-1 for the gas train



construction. Boilers over 12,500,000 BTU/hr input would fall under NFPA 8501 (National Fire Protection Association 1997). Boilers operating at or above 15 psig would be power boilers, and those below 15 psig would be heating boilers (ASME International 1995). CERL researchers were only able to take a brief look at the 13 plants, but they noticed that some of the boilers will need a more detailed examination to verify that acceptable configurations were installed. Although the new METASYS<sup>TM</sup> UMCS system will greatly improve the centralized monitoring and control of the boiler plants, it is recommended that the mechanical pressure gauges, flow meters, and thermometers not be disabled. These local indicators are valuable troubleshooting tools to mechanics when they enter an equipment room.

#### **Building 2701 (Steam)**

Building 2701 is a steam plant with three, 300 boiler horsepower (BHP) boilers. One unit was installed in 1985 and two units were installed in 1993. The water treatment is provided by Coastline (Coastline Products & Chemicals, Houston, TX). Steam is converted into LTHW in the building mechanical rooms to heat the buildings. There is also a requirement for hot water for showers in the barracks served by this plant. Sodium zeolite softeners are used. Maintenance personnel suspect that corrosion is occurring in the condensate return system because there are large amounts of steel corrosion products ("rust") in the condensate. The boiler relief exhaust piping configuration on one of the boilers needs to be verified for compliance with boiler code.

#### **Building 705 (Low-Pressure Steam)**

Building 705 has two Kewanee 65 BHP firetube boilers that operate at 10 to 11 psig.

#### **Building 587 Hospital Plant (Steam)**

The McDonald Hospital Central Heating Plant, Building 587, has two Cleaver Brooks 300 BHP firetube boilers and one Kewanee 150 BHP firetube boiler. There is also an emergency diesel generator set in the plant to provide backup power for the hospital. There appears to be the onset of corrosion of the boiler feed piping due to the use of dissimilar metals.

**Building 2116 (Steam)**

Building 2116 has two 150 BHP boilers and one 125 BHP boiler operating at 45 psig. The 150 BHP units were installed in 1993 and the 125 BHP unit was installed in 1985.

**Building 2719 (Steam)**

Building 2719 has three 300 BHP boilers, which were installed in 1993. Maintenance personnel report large condensate losses. The boiler safety valve exhaust piping needs to be verified for compliance with the boiler code.

**Building 2750 (Steam)**

Building 2750 has two 125 BHP boilers, which were installed in 1983. The boiler safety valve exhaust piping needs to be verified for compliance with the boiler code.

**Building 227 (Steam)**

Building 227 has two Kewanee 300 BHP boilers, which were installed in 1983. The boilers operate at 100 psig. The boiler safety valve exhaust piping needs to be verified for compliance with the boiler code.

**Building 801 (Steam)**

Building 801 has three 350 BHP boilers, which were installed in 1987. There is very little condensate return from outside the plant. The boiler safety valve exhaust piping needs to be verified for compliance with the boiler code.

**Building 414 (Steam)**

Building 414 has two Kewanee 125 BHP boilers, which were installed in 1984. New burners were installed in 1992.

**Building 409 (Steam)**

Building 409 has two Kewanee 100 BHP boilers that operate at 10 psig. The maintainers report that there may be a great deal of water in the oil tank, which will make it difficult to fire oil.

**Building 2406 (Steam)**

Building 2406 has two 70 BHP firetube boilers that operate at 15 psig. There is a relatively new condensate return tank. There is less locally read instrumentation than normally seen in a boiler room.

**Building 1606 (Steam)**

Building 1606 has two 300 BHP firetube boilers that operate at 40 psig and were installed in 1985.

**Building 1411 (Steam)**

Building 1411 has two 200 BHP firetube boilers that operate at 40 psig and were installed in 1985. The boiler safety valve exhaust piping and fuel train need to be verified for compliance with the boiler code.

***Fuel Costs***

Current fuel costs at Fort Eustis are \$0.53/gal (\$3.87/MBtu) for #2 oil and \$3.60/MBtu for natural gas. However, those rates are annual averages. The gas rates at Fort Eustis vary widely over the course of the year. Also there are cost differentials for those buildings on firm (uninterruptible) rates.

**Site Survey: September 1998**

On 15-16 September 1998, the Utilities Modernization Program Support Team conducted a second site visit at Fort Eustis. The purpose of this visit was to review the design submittals from the A/E contractors involved in the project, and to visit several of the boiler plants that are scheduled for modernization.

***Review of Design Submittals***

The team examined the design submittals for 13 central heating plants. One A/E contractor, Dewberry and Davis, is involved with Building 2719. Building 2719 supports bunker training areas and is slated to be converted to geothermal heat pump systems at a cost of \$2.2 million. Another A/E contractor, Greenwood Partnership, is involved with the other 12 central heating plants located in the following buildings: 2701 (steam plant), 705 (low pressure steam plant), 587 (hospital steam plant), 2116 (steam plant), 2750 (steam plant), 227 (steam plant), 801 (steam plant), 414 (steam plant), 409 (steam plant), 2406 (steam

plant), 1606 (steam plant), and 1411 (steam plant). Greenwood Partnership is looking at all of the various options for operating the plants (i.e., steam, decentralization, etc.). Since these projects fall under M&R projects over \$10 million, the DD1391 would have to be reviewed for work classification and for Congressional notification. Design work was scheduled to be completed by the end of the first quarter FY99. As of second quarter FY99, the design was still in progress.

Fort Eustis DPW personnel briefed the team on the methods they used to develop the proposed modernization projects. They used the following information during the process:

- Installation Reports
  - Installation Status Reports (ISR)
  - Backlog Maintenance & Repair (BMAR)
  - Historic Energy Data
  - DUERS
  - DEIS
  - RADDs
  - Utility Summary Notebook (5-year history)
  - Specific Facility/System Analysis
- Inspection Data
  - Annual boiler inspections
  - Distribution (steam shop)
  - Supported facilities (domestic heat)
  - Utility Evaluation (using the Strategic Utility Planning Evaluation Routine, or SUPER).

### ***Boiler Plant Survey***

The team toured Buildings 801, 833 (HQ 7th Transportation Battalion – Junior Non-Commission Officers Course), 2701, 2719, 2716 (Aircraft Armament Division), 587, and 705. Some of these plants were also surveyed during the March 1998 site visit. Any new observations and information are noted below.

#### **Building 801**

Building 801 currently has three 350 BHP Kewanee natural gas boilers. The central UMCS is fully automatic and computerized and was installed during the summer of 1999. The aboveground line distribution is being retained.

**Building 833**

Building 833 has a packaged Lennox unit inside the building, with an aging packaged air-conditioning (A/C) unit outside the building.

**Building 2701**

No new information to report.

**Building 2719**

Building 2719 currently has three nonoperational boilers and will be converted to geothermal heat pumps. There are five test wells, each 300 ft deep. New steel trunk lines are being installed for the geothermal system because the existing piping is in poor condition. The building needs a set of water softeners.

**Building 2716**

Building 2716, which houses COBRA AH-1S helicopters, has infrared heating lamps.

**Building 586**

The team viewed the Tecochill natural gas chiller located in Building 586. The roof of the building has been completed.

**Building 705**

No new information to report.

***Aboveground Distribution System***

The team was able to view some of the aboveground lines and steam traps. The lines that were surveyed were found to be in relatively good condition, with only a few repairs that need to be done.

**Energy Screening Analysis**

The CERL-developed energy screening tool mentioned previously was used to develop cost curves for different heating systems based on previous DoD plant studies, data from the Redbook (U.S. Army Center for Public Works 1997), and

utility bills from Fort Eustis. The energy density of the entire cantonment area is about 0.815 MBtu/hr/acre. The areas near the barracks may have energy densities that are much higher than the base average. The curves indicate central plants are favorable in areas where the density is above 0.6 MBtu/hr/acre (Figure 1). Decentralized systems are definitely more favorable in regions with energy densities below 0.3 MBtu/hr/acre. This preliminary screening indicates that central heating systems that are in good condition should be preserved.

## HEATMAP Analysis

CERL has part of the data required to perform a HEATMAP analysis for Fort Eustis. A HEATMAP analysis can be done if needed, pending the availability of FY99 funds. HEATMAP can be used to calculate the troop housing area energy densities and to analyze various modernization scenarios as required by Fort Eustis, TRADOC, or ACS(IM).

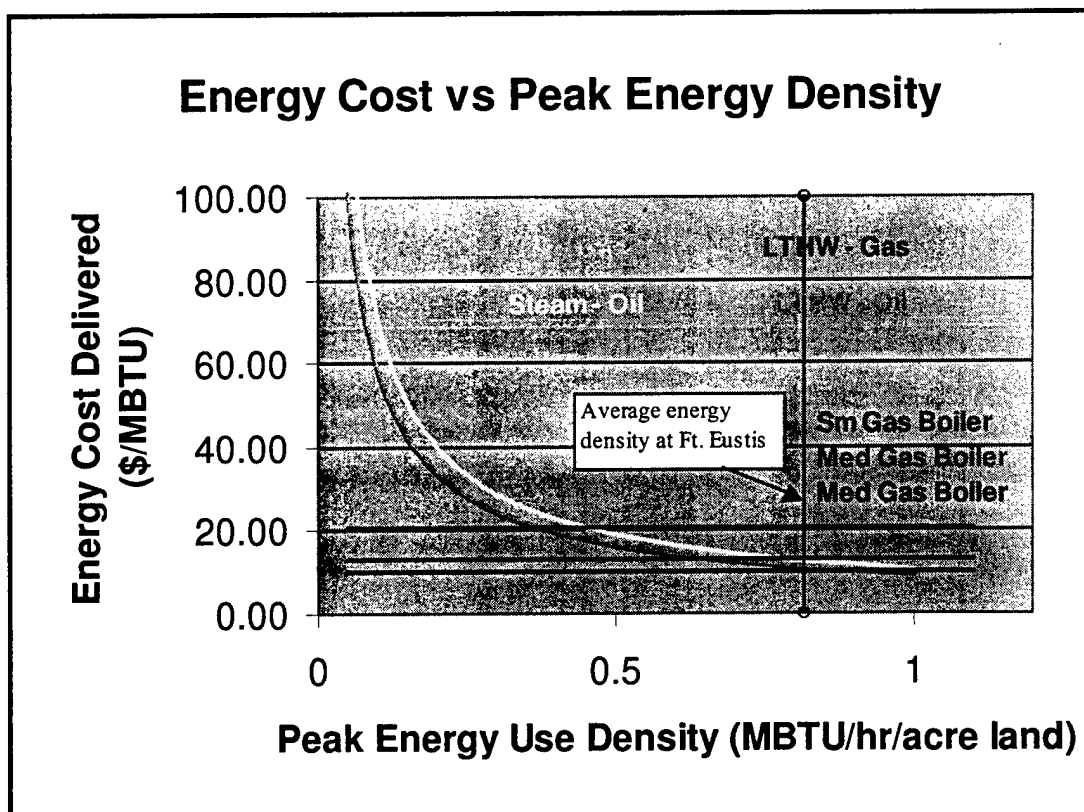


Figure 1. Energy density data for Fort Eustis.

## Summary and Recommendations

1. The March 1998 site survey revealed that there may be some system configuration problems at Fort Eustis in the fuel and steam piping. It is recommended that a more detailed examination be conducted to evaluate compliance with the boiler code. The steam safety valve discharge piping should be as short and straight as possible to avoid back pressure and water hammer problems. Additionally, there should not be any mechanical loads on the steam safety valves as any bending stresses on the valve body will affect the valve performance. It is possible for improperly installed discharge piping to prevent a safety valve from operating.
2. Aboveground steam piping is the safest, most reliable, and least expensive system to install and maintain. The lines that were surveyed were found to be in relatively good condition. They require only a few repairs.
3. Loss of condensate is a problem at Fort Eustis. Some of the condensate piping may need repair due to condensate grooving. Some of the underground sections may have failed as well. Corrosion of the condensate lines indicates that the boiler water treatment program is deficient or that untreated water is entering the system somewhere (for example, at a leaking heat exchanger). A chemical analysis of the boiler water and the condensate should be done to diagnose the cause of the problem and to determine the proper remedy. Schedule 80 pipe is the recommended type used for condensate return piping at outer ends of the system for proper chemical carryover. Fiberglass reinforced plastic (FRP) piping is not allowed because it cannot tolerate high temperatures. If most of the buildings convert steam to LTHW for space heating, the steam pipe sizing should be checked for conversion to LTHW distribution if the condensate systems are completely failed.
4. Dissimilar metal (galvanic) corrosion was observed in the boiler feed piping at one of the plants. It is recommended that piping/components constructed of dissimilar metals be electrically isolated from each other to prevent this type of corrosion from occurring.
5. The energy screening tool indicates that central plants are favorable at Fort Eustis in areas where the energy density is greater than 0.6 MBtu/hr/acre, and that decentralized systems are more favorable in regions with energy densities below 0.3 MBtu/hr/acre. Based on the data provided during the site survey, the energy density of the entire cantonment area is about 0.815 MBtu/hr/acre. Therefore, central heating systems at Fort Eustis that are in good condition should be preserved.
6. The utility provider at Fort Eustis has a utility service contract (USC) available for Fort Eustis to use. It is recommended that Fort Eustis obtain an accurate

baseline measurement of the current cost of operation. The importance of this cannot be overemphasized. If the baseline is overestimated, the base risks "overpaying" for saving. If the baseline is underestimated, the contractor may not be able to find enough energy conservation opportunities (ECOs) to get a fair return on their investment. CERL can provide technical assistance with screening for ECOs and estimating the baseline cost (Chapter 9).

7. Based on observations made during the September site visit, architectural corrections on the boiler plant (e.g., asbestos removal) should be made.
8. The DD1391 write-up for central heating plant modernization needs to be agreed on and sent to CEISC for work classification prior to Congressional approval since the M&R projects are greater than \$10 million.
9. CERL can provide input to the design reviews by providing HEATMAP analyses and reviewing stages of the designs as they become available. Electronic (AutoCAD) maps of the distribution system are needed for this.
10. The thermal calculations for sizing geothermal systems should be reviewed. CERL can provide assistance with this.
11. It is suggested that Fort Eustis use additive bid items in the contract so that as much work as possible is accomplished if bids do not match project estimates.



## 4 Fort Carson Analysis

### Background

The base operations at Fort Carson have been contractor operated for almost 10 years. The central cooling plants, central heating plants, distribution systems, and building heating, ventilating, and air conditioning (HVAC) systems are all operated and maintained by Pacific Architects and Engineers Incorporated (PAE). In FY96 PAE charged Fort Carson \$68K for chiller operations, \$64K for chiller maintenance, \$531K for heat system maintenance, and \$389K for heat system operation. The cooling season runs from June 15 to September 15 and the heating season runs from October 15 to May 15. The cantonment area encompasses approximately 2500 acres of land and 12.4 million sq ft of buildings.

High temperature hot water (HTHW) and steam are used to deliver heating and DHW to the buildings. All of the plants except Building 403 are gas and oil fired. Building 403 is gas fired only.

### Site Survey

CERL representatives visited Fort Carson, CO, 23-24 March 1998 to collect data and interview energy personnel. The following sections summarize the information obtained during the visit.

#### *Heating Plant Survey*

In general, most of the plants and mechanical rooms were in good condition. An exception to this was the main central chiller plant at Building 1864, which was in urgent need of repair for the upcoming cooling season. Fort Carson was in the process of re-tubing one of the chillers to meet this season's cooling needs. Fort Carson is allowing their energy savings performance contract (ESPC) to develop a proposal to replace two of the failing chillers.

**Building 1860 (HTHW)**

Building 1860 is an HTHW plant with three 40 MBtu units. Two units were manufactured by Union Iron Works and one unit was manufactured by Flow Control. A new controls upgrade is nearing completion at the plant.

**Building 1864 (Chilled Water)**

Building 1864 has three Trane LiBr 1500 ton absorption chillers. HTHW from Building 1860 provides the heat for the chillers. Two of the chillers are suspected to have over 10 percent tube failure, which necessitates re-tubing as discussed above. The chillers were installed in 1973.

**Building 6290 (HTHW and Steam)**

Building 6290 has two IBW 20 MBtu HTHW units and two 750 BHP Burnham firetube boilers. The HTHW units serve the Evans Army Hospital. The plant is located unusually far from the new hospital, which means that heat losses in the distribution lines will be larger than in typical hospital plant configurations. The operators report that there is not quite 100 percent backup capability at the plant (based on the design daytime conditions). The logs show that, for the mild winter in 1997, only one unit was fired at a time. During the summer, the load turns down such that the units have to be hand fired. The steam boilers serve an area that is scheduled for demolition in the long range plan and therefore the building load would be reduced. A few of the historically relevant buildings will remain and probably be converted to decentralized boilers. Some of the buildings have already been demolished and the operators suspect that larger-than-normal line losses are occurring due to the piping being disturbed and incomplete pipe capping during demolition.

**Building 9609 Butts Field (Steam)**

Building 9609 has three 175 BHP Burnham firetube boilers. These units were installed in 1995. Access to Butts Field is restricted so CERL researchers did not get a chance to visit the plant. Fort Carson does not report any steam distribution problems.

**Building 403 (Steam)**

Building 403 has one 125 BHP Burnham firetube boiler, which was installed in 1997 and one 525 BHP Cleaver Brooks watertube boiler. This plant served a

laundry in the past. Now that the laundry is gone, the smaller boiler is adequate to provide heat for the remaining buildings.

### Fuel Costs

Current fuel costs at Fort Carson are \$0.70/gal (\$5.18/MBtu) for #2 oil, \$0.99/gal (\$10.42/MBtu) for propane, and \$2.57/MBtu for natural gas. Fort Carson and the Air Force Academy have combined their fuel needs to negotiate good interruptible and firm gas rates from the City of Colorado Springs.

### Energy Screening Analysis

The CERL-developed energy screening tool discussed previously was used to develop cost curves for different heating systems based on previous DoD plant studies, Redbook data, and utility bills from Fort Carson (Figure 2). Although the energy density of the entire cantonment area is about 0.311 MBtu/hr/acre, there are areas near the barracks where the density is much higher. The curves indicate central plants are favorable in areas where the density is above 0.65 MBtu/hr/acre. Decentralized systems are definitely more favorable in regions with energy densities below 0.3 MBtu/hr/acre.

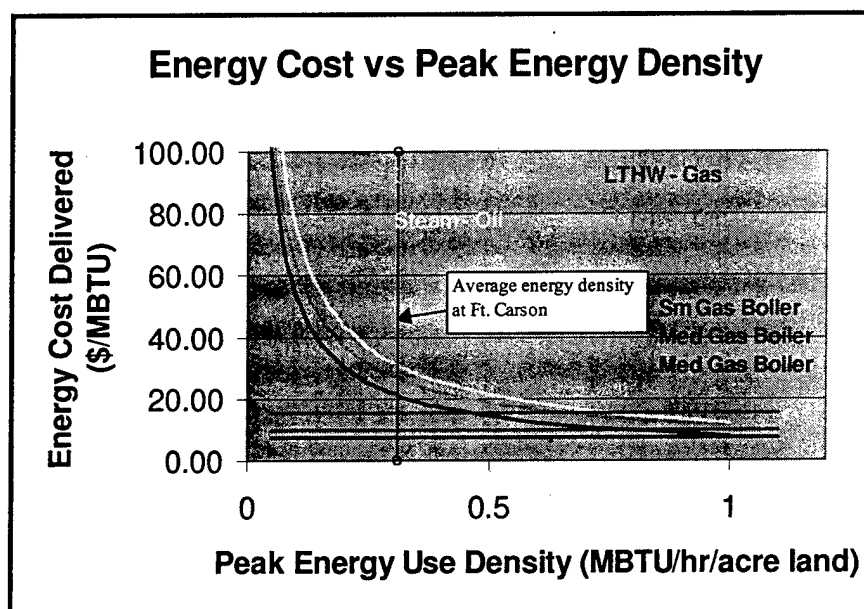


Figure 2. Energy density data for Fort Carson.

This preliminary screening indicates that central heating systems that are in good condition should be preserved. Fort Carson's actual cost curves for the central plants may be lower. (The cost billed by the contractor to operate and maintain the heating systems was \$1.53/MBtu delivered to the building.) This is at the lower end of the nonfuel operation and maintenance (O&M) costs reported by industry and institutional steam plants.

## HEATMAP Analysis

Fort Carson DPW personnel provided an electronic map of the distribution system, building load data, and boiler logs. This data was used to conduct a HEATMAP analysis on the existing system.

## Summary and Recommendations

1. No serious problems have been observed at the Fort Carson heat plants. Some of the deficiencies reported at Building 6290 may not be pertinent once the demolition is complete in the adjacent barracks.
2. The main HTHW system off of Building 1860 is a main and lateral system. Some valve repairs may be needed. It is difficult to manage outages in some sections due to the valve condition and piping configuration. However, PAE reports that unearthed underground sections appear to be in good condition. Work on the HTHW system would probably focus on repairs and modifications to make the system more reliable and flexible. If the system had two mains or a loop, major sections could be isolated, depressurized, and cooled down to allow repairs.
3. Although the Army CEP Modernization is not intended to fund chiller repairs, the failure of the HTHW fired absorption chillers has created an urgent need.
4. The energy screening tool indicates that central plants are favorable at Fort Carson in areas where the energy density is greater than 0.65 MBtu/hr/acre, and that decentralized systems are more favorable in regions with energy densities below 0.3 MBtu/hr/acre. Based on the data provided during the site survey, the energy density of the entire cantonment area is about 0.315 MBtu/hr/acre. Therefore, central heating systems at Fort Carson that are in good condition should be preserved.
5. Fort Carson is in the initial stages of establishing an ESPC. Fort Carson is concerned that CEP repairs may interfere with the bundling of ECOs in the ESPC contractor's proposal. The importance of obtaining an accurate baseline measurement of the current cost of operation cannot be overemphasized. If the baseline is overestimated, the base risks "overpaying" for saving. If the baseline is

underestimated, the contractor may not be able to find enough ECOs to get a fair return on their investment. CERL can provide technical assistance with screening for ECOs and estimating the baseline costs (Chapter 10).

## 5 Fort Drum Analysis

### Background and Problem

The existing direct buried HTHW piping system at Fort Drum was installed in 1987. The system has failed prematurely due to leaks in both the conduit and the carrier pipe. Failures in the conduit were evidenced by its inability to hold pressure. Failures in the carrier pipe were evidenced by the leakage of treated HTHW into the annulus (area between the carrier pipe and conduit).

The proposed modernization project consists primarily of replacing an existing direct buried HTHW distribution system that is in poor condition. The original replacement design was a shallow concrete trench system with occasional short runs of aboveground piping. CERL was asked to investigate the degradation problems in the existing system and to predict the remaining life of the direct buried carrier and conduit pipes.

### Approach

The first step was to gather background data on the existing HTHW piping system at Fort Drum. The Fort Drum DPW was asked to collect water samples from the following locations: (1) annulus between manholes and (2) native groundwater outside of the direct buried piping system. Piping samples were also obtained by the DPW and shipped to CERL.

The second step was to analyze the chemistry of the water samples and to examine the pipe samples (including measurements of the remaining wall thickness).

The third step was to use the SCALER engineered management system (EMS) to predict the remaining life of the carrier pipe. SCALER was developed by CERL and Forces Command (FORSCOM) in the late 1980s to predict the effects of corrosion on water piping based on physical information about the piping system and the chemistry of the water conveyed (Van Blaricum, Knoll, and Hock 1990). Water chemistry and pipe data were entered into SCALER and prediction reports were generated.

## Laboratory Results

Table 2 lists the results of the water chemistry testing for Fort Drum. Sample 1 is the normal groundwater outside of the direct buried pipe system. The laboratory test results indicate that this water is very slightly corrosive to steel due to the negative Langelier Index and the amount of dissolved CO<sub>2</sub> and high chloride content.

Sample 2 was obtained from the annulus between the carrier and conduit pipes at manhole 73. This water had a temperature of 162 °F at the time of sampling. The laboratory test results indicate that this water is very corrosive to steel due to the high dissolved CO<sub>2</sub>, negative Langelier and high Ryznar Indices. There is also little alkalinity or total hardness in this water.

Sample 3 was obtained from the annulus between the conduit and carrier pipes at manhole 19. This water had a temperature of 188 °F at the time of sampling. The laboratory test results indicate that this water is not expected to be corrosive to steel due to the elevated pH (11.8), very high hardness and alkalinity, positive Langelier and low Ryznar Indices. This water also had a Tannin content of 9.9 mg/L, which indicates that treated HTHW has leaked from the carrier into the annulus. The interesting thing about this water sample is that the mixing of the groundwater with the treated water has rendered it noncorrosive.

Physical examination of the pipe sample received from Fort Drum revealed very slight corrosion on the outside surface of the conduit. Much of the original protective coating was intact. However, the inside surface of the conduit showed evidence of pitting corrosion. Examination of the carrier pipe revealed pitting corrosion on the outside surface and minor pitting on the inside surface. The carrier pipe's wall thickness was measured as 0.20 in.

## SCALER Analysis

The water chemistry and pipe data were entered into the SCALER EMS program. SCALER predicts when a pipe failure will occur based on physical information about the piping system and the water conveyed. It uses mathematical prediction models to forecast the remaining life of a pipe. The condition of a pipe is expressed as a Corrosion Status Index (CSI), which ranges from 100 (new) to zero (completely corroded).

Table 2. Fort Drum water chemistry data.

Parameter	Sample 1: Normal Groundwater	Sample 2: Water from Annulus at Manhole 73	Sample 3: Water from Annulus at Manhole 19
pH	7.20	8.38	11.80
Temperature (°F)	77.00	162.00	188.00
Oxygen (mg/L)	0.00	0.00	5.00
Carbon Dioxide (mg/L)	5.80	11.20	6.00
Aluminum (mg/L)	0.17	0.16	4.37
Copper (mg/L)	0.01	0.00	0.03
Iron	0.04	0.12	0.13
Magnesium (mg/L)	11.10	0.11	8.03
Manganese (mg/L)	0.01	0.00	0.00
Sodium (mg/L)	134.00	39.20	164.20
Tin (mg/L)	0.15	0.00	0.00
Zinc (mg/L)	0.00	0.00	0.18
Chloride (mg/L)	170.00	18.00	214.00
Phosphates (mg/L)	0.42	0.00	0.00
Phosphonate (mg/L)	0.00	0.50	0.00
Silicate (mg/L)	7.90	0.00	0.00
Sulfate (mg/L)	92.00	38.00	58.00
Sulfide (mg/L)	0.00	12.68	0.00
Total Hardness (mg/L)	312.00	3.30	211.50
Methyl Orange Alkalinity (mg/L)	296.00	46.00	512.00
Phenolphthalein Alkalinity (mg/L)	0.00	0.00	210.00
Bicarbonate Alkalinity (mg/L)	351.00	54.30	327.30
Carbonate Alkalinity (mg/L)	8.50	0.00	5.80
Total Alkalinity (mg/L)	296.00	46.00	512.00
Total Dissolved Solids (mg/L)	798.00	191.30	1017.00
Tannin	0.00	0.00	9.90
Langelier Index	-0.15	-14.00	4.28
Ryznar Index	7.50	14.00	3.24

SCALER used the prediction model for pitting attack of steel and galvanized steel pipes by hot water. The pitting attack is the most prevalent and insidious form of corrosion for steel and galvanized steel pipes. Pitting attack was observed on the pipe sample from Fort Drum. Pitting results in flow-restricting tubercle formation and, eventually, pinhole-type leaks. Pitting has been found to be positively correlated with the stability (Ryznar) index. The equation used to predict the depth to which a pit will propagate in "t" years in hot water can be estimated by using the following equation:



$$P = 0.0261(SI - 7)t^{1/3}[\text{inch}]$$

Eq. 1

where:

SI = Stability Index = Ryznar Index

The results of the prediction are shown in Figures 3 to 5.

WATER QUALITY ID : GROUNDWATER, WQ1  
 WATER TEMPERATURE (F) : 135.00 AVERAGE VELOCITY (FPS): 0.20  
 PIPE TYPE : Sch.40 Galv.Stl. WALL THICKNESS (inch) : 0.2180  
 YEAR INSTALLED : 1987 PIPE SIZE - ID (inch) : 2.0000  
 PREDICTED FIRST LEAK (CSI<=30): None ACTUAL FIRST LEAK : No leak recorded.

Method of CSI calculation : Hot-Water Pitting Corrosion of Galvanized Steel

Formula of CSI calculation: Max.Pit Depth =  $0.0261(7.50-7) * (\text{time} \wedge 1/3)$ 

Pit Depth (in inches) &amp; Time (in years)

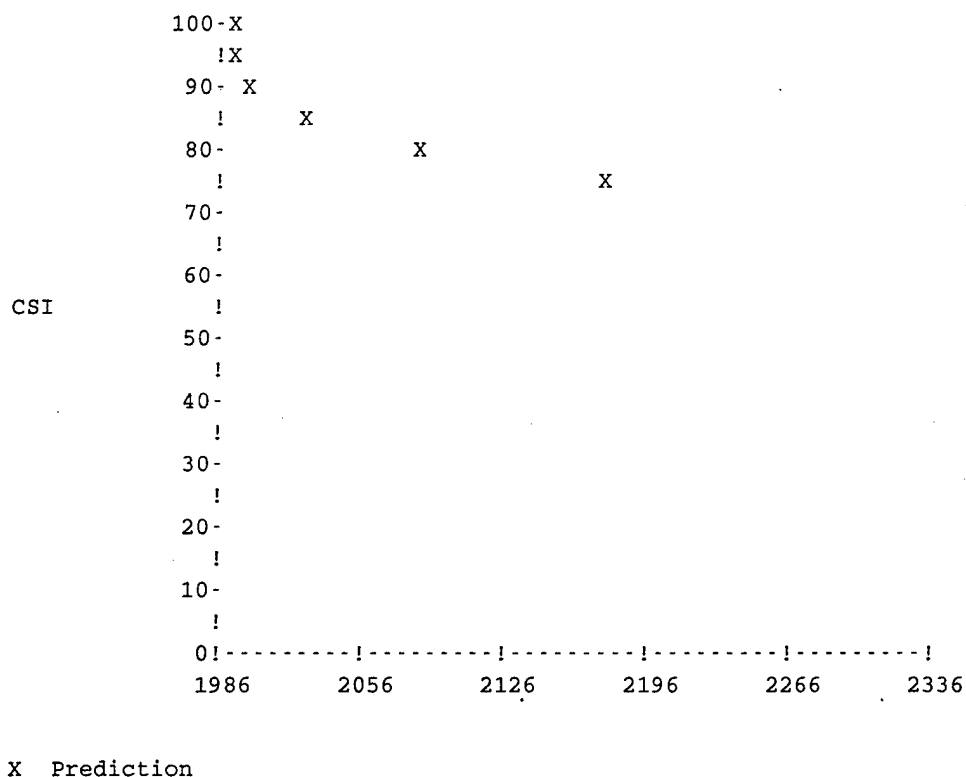


Figure 3. SCALER prediction for Fort Drum groundwater sample.

WATER QUALITY ID : Manhole 73, WQ2  
 WATER TEMPERATURE (F) : 135.00 AVERAGE VELOCITY (FPS): 0.20  
 PIPE TYPE : Sch.40 Galv.Stl. WALL THICKNESS (inch) : 0.2180  
 YEAR INSTALLED : 1987 PIPE SIZE - ID (inch) : 2.0000  
 PREDICTED FIRST LEAK (CSI<=30): 1989 ACTUAL FIRST LEAK : No leak re-  
 corded.

Method of CSI calculation : Hot-Water Pitting Corrosion of Galvanized Steel  
 Formula of CSI calculation:  $\text{Max.Pit Depth} = 0.0261(14.00-7) * (\text{time} \wedge 1/3)$   
 Pit Depth (in inches) & Time (in years)

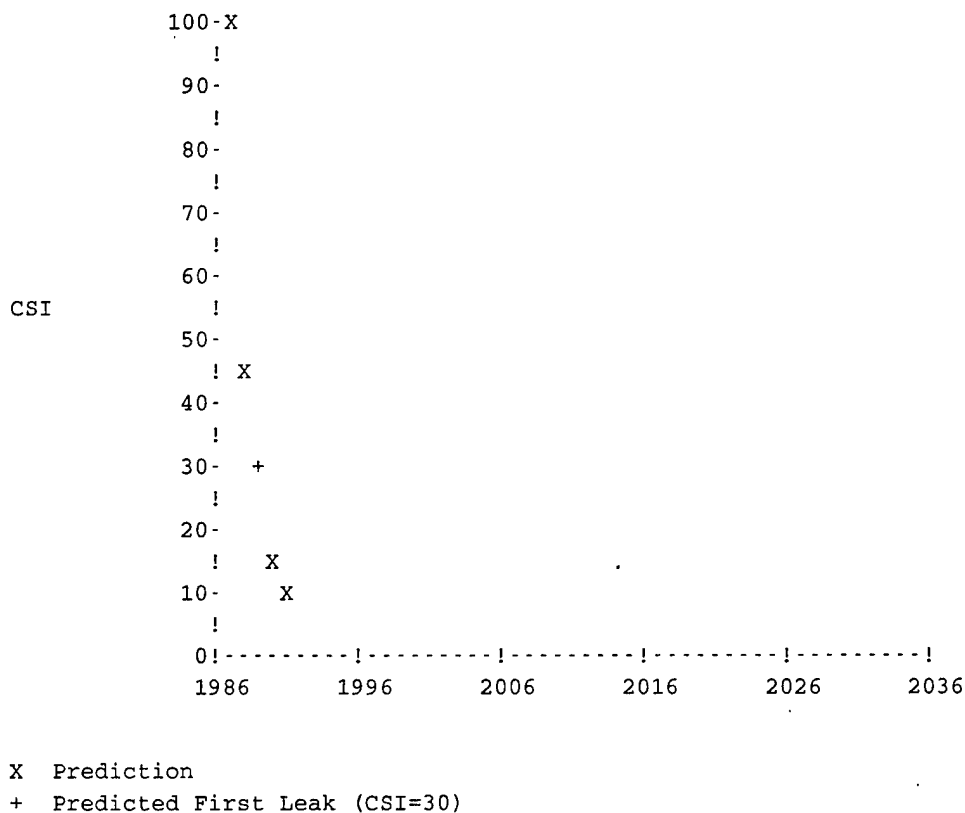
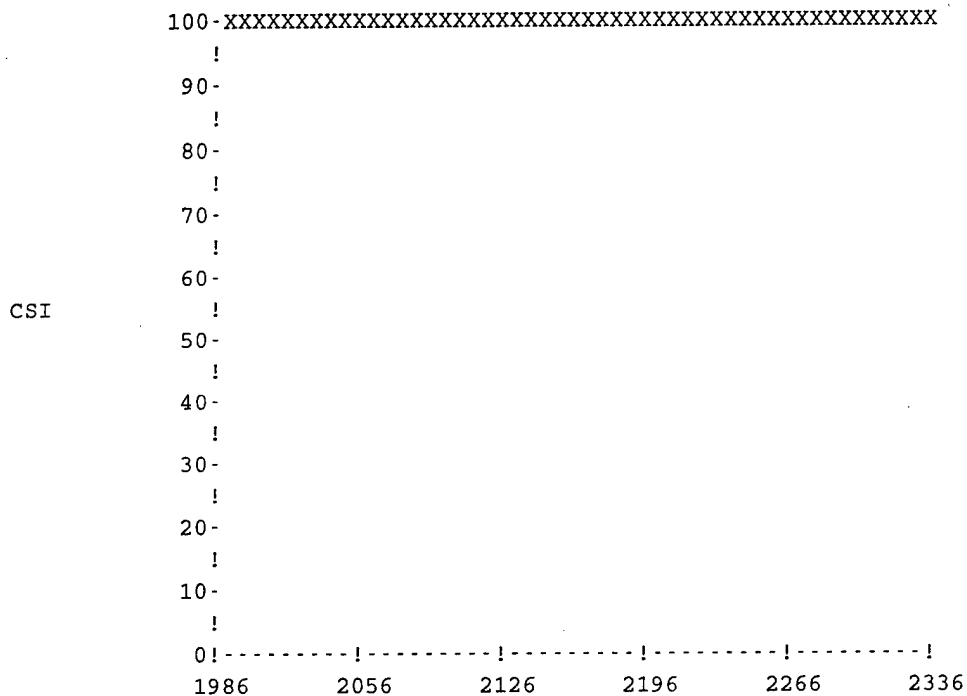


Figure 4. SCALER condition prediction for water from Fort Drum manhole 73.

WATER QUALITY ID : Manhole #19, WQ3  
 WATER TEMPERATURE (F) : 135.00 AVERAGE VELOCITY (FPS): 0.20  
 PIPE TYPE : Sch.40 Galv.Stl. WALL THICKNESS (inch) : 0.2180  
 YEAR INSTALLED : 1987 PIPE SIZE - ID (inch) : 2.0000  
 PREDICTED FIRST LEAK (CSI<=30): None ACTUAL FIRST LEAK : No leak recorded.

Method of CSI calculation : Hot-Water Pitting Corrosion of Galvanized Steel  
 Formula of CSI calculation:  $\text{Max.Pit Depth} = 0.0261(3.24-7) * (\text{time} \wedge 1/3)$   
 Pit Depth (in inches) & Time (in years)



X Prediction

NOTE: For a stability (Ryznar) index less than 7, a coefficient of 0 was used.

Figure 5. SCALER condition prediction for water from Fort Drum manhole 19.

## Discussion

Based on SCALER predictive models for pitting corrosion of galvanized steel at elevated temperatures, the carrier pipe (2-in. ID x 0.218-in. wall thickness) could fail by pitting corrosion in a very short time (less than 5 years). This prediction is upheld by the fact that Fort Drum has pressure tested the annulus between the carrier and conduit, and could not maintain the required 15 psi for 1 hour. In addition, treated HTHW was detected in one of the water samples from the annulus at manhole 19. Since the groundwater is only slightly corrosive to steel, the most likely scenario for failure would be the following:

1. Groundwater enters the annulus between the conduit and carrier pipes. There are at least three likely causes of the groundwater intrusion. The most likely cause is seepage through the drain or vent in the end cap at the manhole. (This assumes that the manhole was flooded.) Another possible cause is conduit penetration due to soil-side pitting corrosion. The probability of this is lower than seepage through the drain or vent (due to the longer time required). Previous work done at Fort Drum has indicated that the soil is not very corrosive. The soil was found to have a pH in the range of 6.9 to 8.0, which is considered neutral. Moreover, the PIPER program estimates a life of 17 years for the steel conduit. This is considerably longer than the time for failure predicted by SCALER for pitting corrosion of the interior of the carrier pipe. However, Fort Drum personnel have reported that failure of the conduit did occur at the conduit/manhole junction due to galvanic and/or concentration cell corrosion. Cathodic protection would have probably prevented this type of failure. The third possible cause of groundwater intrusion is defective weld joints. DPW personnel reported that they had observed water intrusion into the annulus due to lack of complete weld joints in the conduit at the expansion loops.
2. The heated groundwater (minimum 162 °F) is chemically altered and becomes soft and very aggressive or corrosive to steel.
3. The boiling groundwater causes severe pitting corrosion on the interior surface of the conduit. This allows more groundwater to intrude. The physical examination of interior surfaces of the conduit did not reveal any significant difference in the amount of corrosion product, e.g., uniform pitting around the circumference of the conduit.
4. Eventually (less than 5 years) the very corrosive groundwater causes failure of the exterior surface of the carrier pipe by pitting corrosion.
5. This allows treated HTHW to enter the annulus and mix with the groundwater, rendering it noncorrosive.
6. Examination of the interior surface of the carrier pipe revealed little or no visible corrosion. This indicates that the CHP has an excellent water treatment program.
7. Eventually the entire system fails (in as little as 5 years) and requires total replacement.

Note that the application of cathodic protection would most likely not have prevented the failure of either the conduit or carrier pipes due to a lack of weld or failure to install drain plugs or vent pipes. This is because the pitting corrosion was initiated on the inside of the annulus. This scenario is based on failure of the conduit by pitting corrosion on the interior surface due to groundwater intrusion. If the conduit failed due to soil-side corrosion or galvanic corrosion at the conduit/manhole junction, then cathodic protection would be an

effective corrosion prevention measure. Cathodic protection should be installed on any direct buried pipe at Fort Drum.

### **Conclusions from Fort Drum Analysis**

Based on the water chemistry, pipe examination, and SCALER prediction models, the following conclusions can be made concerning the direct buried HTHW piping system at Fort Drum:

1. The remaining life of the piping system could be as little as 5 years due to the failure of the carrier pipe by pitting corrosion.
2. The primary failure mode of the conduit appears to be pitting corrosion induced by corrosive boiling water. The groundwater intrusion most likely occurred at the manhole or expansion loops.
3. The primary failure mode of the carrier appears to be pitting corrosion of the exterior surface due to exposure of boiling ground water. The very slightly corrosive groundwater is chemically altered by boiling with the insulated materials over long periods of time (greater than 90 days).
4. The conduit pipe will not pass a pressure test (15 psi for 1 hour). This indicates penetration, which allows continual intrusion of groundwater.
5. There is evidence of at least one failure of the carrier pipe near manhole 19. The water analyses revealed the presence of treated HTHW in the pipe annulus.

### **Recommendations for Fort Drum**

Based on the results of the analysis, the following recommendations can be made concerning the direct buried HTHW piping system at Fort Drum:

1. The direct buried HTHW pipe system at Fort Drum should be replaced with a shallow trench or aboveground pipe system according to AR 420-49.
2. Prioritization of replacement sections should be based on the predictive models developed for the SCALER/G-PIPER EMS programs.

## 6 Fort Campbell Analysis

### Background

Fort Campbell is submitting a utilities modernization project for funding as part of the Army's Utility Modernization Program. CERL was asked to conduct a HEATMAP analysis of three proposed alternatives to estimate construction and fuel consumption costs. The alternatives were:

1. A new steam system using the existing boilers
2. A new LTHW system using the existing boilers and cascade heaters
3. A new LTHW system using three new hot water generators, two at 35 MBtu/hr and one at 15 MBtu/hr.

All three alternatives included shallow trench piping and one new low NO<sub>x</sub> boiler or hot water generator (funded in a separate project).

### *System Description*

The existing heating system at Fort Campbell was completed in 1977. Boiler Plant 3902 consists of two 50 MBtu/hr #2 oil/gas fired boilers and one 15 MBtu/hr #2 oil/gas fired boiler. All the boilers are of water-tube design and were manufactured by Nebraska Boiler. The working steam pressure is 92 psig.

A previous study completed by Schmidt and Associates, Inc. (SAI) revealed that the existing boilers were in good condition and operating near the design efficiency of 80 percent. An additional 20 plus years of boiler life is expected. However, the direct buried steam supply and condensate return systems are in poor condition and result in high energy losses. This system currently serves two barrack complexes and the Lee Family Housing Area. Installation of an alternate means of heating and cooling is planned for the family housing area, therefore it is not included in this study.

### *Fort Campbell Heat and Steam Requirements*

Steam is used primarily for heating and DHW production. Buildings 3603 and 4061 require steam for humidification and kitchen equipment. Of the 54

buildings on the system, 19 use steam directly in their heating system. In the other buildings, steam is converted to LTHW in the mechanical room before it is distributed inside the building.

### ***Fuel Costs***

Current fuel costs at Fort Campbell are \$0.60/gal for #2 oil and \$3.31/MBtu for natural gas.

## **HEATMAP Analysis**

### ***Assumptions and Data Used for All HEATMAP Scenarios***

This section explains the sources of data and assumptions that were used throughout all three of the HEATMAP scenarios that were analyzed for Fort Campbell, KY. Assumptions that are specific to individual scenarios are explained in the subsequent sections.

Data used for the HEATMAP analysis included an electronic map of the distribution system, building load data, boiler logs, and operation and maintenance costs from a previous study performed by Systems Engineering Management Corporation (Systems Corp). All of this data was used to validate the HEATMAP model for the existing system. The data was then used to estimate distribution system costs and annual fuel consumption for new steam and LTHW systems using shallow trench piping systems.

Estimates for boiler retrofit costs were taken from the 1997 R.S. Means data and did not include costs for the installation of a new low NO<sub>x</sub> boiler. The boiler is to be funded from another project.

It was assumed that natural gas was the only fuel used for the new scenarios.

Boiler demolition cost estimates were obtained from a project at Fort Dix, NJ, where similar size boilers were being removed from an existing plant.

A cost estimate for converting the 19 buildings that use steam directly in the heating system to LTHW systems was obtained from the Systems Corp study. Their total estimate for the conversion was \$1,300,000.

Building category codes and building loads areas were obtained from the Systems Corp study. Climate data for Nashville, TN, was used for the HEATMAP

analysis because the weather conditions are similar to those encountered at Fort Campbell. Nashville has 3,696 annual Heating Degree Days (HDD) and a design temperature of 14 °F.

A study period of 20 years was used for all scenarios.

### **Existing Steam System ("Status Quo")**

#### **Prediction of System Life and Future Repair/Replace Costs**

In this scenario it was assumed that the entire distribution system would be replaced in kind over the next 15 years. Therefore 1/15 of the cost of a new distribution system was included each year for repair. Since the life expectancy of a direct buried system is approximately 15 years, the sections repaired the first year would begin to fail in year 16. Thus this repair cost is included for the entire 20-year study period. If a greater proportion of the system were replaced earlier in the study period, the life cycle cost of this option would increase.

The cost for the direct buried piping was assumed to be the same as the cost for a shallow trench system. Even though replacement of the entire system with direct buried piping would cost approximately 80 percent of the cost of a shallow trench system, incremental replacement of the system would result in increased cost/ft due to increased overheads and contingencies for the contractors and design engineers for each of the smaller projects.

#### **Estimated System Heat Loss**

The system loss for the distribution system is assumed to be approximately 10 MBtu/hr for the entire study period, since the system is only being replaced as it fails. The effect of the system loss is felt throughout the season. At part load conditions, the system loss will be nearly the same as during peak load conditions.

Table 3 summarizes costs for this option.

**Table 3. HEATMAP data for existing steam system at Fort Campbell.**

Peak Building Load (MBtu/hr)	52.1
Annual Building Load (MBtu/yr)	97,940
Peak Plant Steam Load (MBtu/hr)	59.8
Annual Plant Fuel (MBtu/yr)	231,925
Annual Operating Cost (\$)	\$ 1,055,000
Piping Repair Cost (\$/year)	\$ 397,400
20 yr LCC Fuel Cost @\$3.31/MBtu (\$)	\$ 13,741,000
Net PW@ \$3.31/MBtu (97 \$)	\$ 22,398,000



### ***Validation of HEATMAP Model***

The HEATMAP simulation relies on several estimates and assumptions to make calculations about the flow characteristics and thermal performance of the heat distribution system. It is therefore important to use actual steam flow and fuel consumption data from the installation to verify that the simulation results are reasonable. If the HEATMAP results compare well with the actual data, this means that the assumptions and estimates used in the model are valid and that they may be applied to the other scenarios as appropriate. It is unlikely that the results will match exactly; the objective here is to verify that the simulation results are "in the ballpark."

Data from the Fort Campbell boiler logs was used to plot the average hourly steam flow versus the average daily temperature (Figure 6). The data was used to validate HEATMAP's annual heating load calculation in the following manner. Thermal losses were identified from the plot of steam flow (Figure 6). The plot shows large thermal losses of nearly 8,500 lb/hr or 10 MBtu/hr, which equates to an annual consumption of 110,000 MBtu of natural gas. Fort Campbell personnel reported total annual fuel consumption to be 231,000 MBtu. Subtracting the fuel consumed by the annual thermal loss (110,000 MBtu) from the total fuel consumption leaves 121,000 MBtu of natural gas to provide for the actual heating load. As mentioned previously, the SAI study indicated that the boiler combustion efficiency was about 80 percent. Multiplying the fuel available for heating (121,000 MBtu) by the 80 percent efficiency gives an annual heating load estimate of approximately 97,000 MBtu. This is very close to the 97,940 MBtu calculated by HEATMAP (Table 3).

To further validate the assumptions made in the HEATMAP model, the load on the plant was calculated for the design day. As discussed previously, the design day temperature was assumed to be 14 °F. Reading from Figure 6, the heating load for a temperature of 14 °F is approximately 50,000 lb/hr.

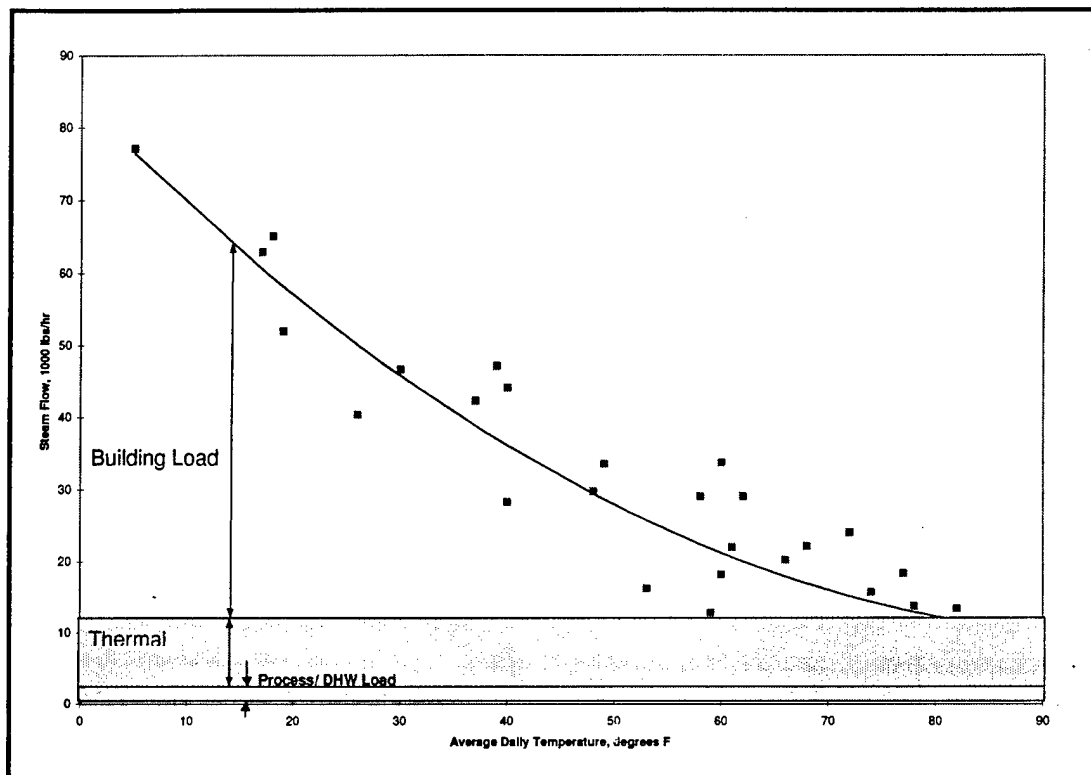


Figure 6. Average hourly steam flow vs. average daily temperature data for Fort Campbell Plant 3902.

An additional 2500 lb/hr are added to the estimated peak heating load to account for the process load and the peak DHW load, which brings the estimated total peak consumer load for the base to 52.5 lb/hr. An additional 10 MBtu/hr of distribution system losses would result in a peak plant output of 62.5 MBtu/hr. HEATMAP estimates the peak plant steam load to be 59.8 MBtu/hr. This is slightly lower than the load calculated from the actual Fort Campbell data, but it is still a reasonable estimate.

### ***New Steam System***

In this scenario it is assumed that the entire steam distribution system will be replaced with a shallow trench steam distribution system.

### **Calculation of Capital Costs**

The cost for the shallow trench piping for this scenario was calculated at nearly \$6 million by the HEATMAP program using the optimized pipe diameters.

### Estimation of Operation and Maintenance Costs

The maintenance cost was assumed to be the equivalent of one full time employee (FTE) (\$30,000) plus an additional \$15,000 for steam trap maintenance for a total of \$45,000 per year. There are approximately 150 steam traps in the system. It was assumed they would be replaced every 3 years at \$300 per trap. This maintenance cost is included for the entire study period.

### Estimation of Future Replacement Costs

Since the life expectancy of a shallow trench steam system is approximately 40 years, no large scale failures would be expected to appear during the study period.

### Estimation of System Heat Loss

The heat loss for the distribution system was estimated to be 3.6 MBtu/hr for the entire study period. The effect of the system loss is felt throughout the season. At part load conditions, the system loss will be nearly the same as during peak load conditions. The estimate for system heat loss assumes that the system would be maintained properly. If the system (especially the steam traps) is not maintained properly, the thermal losses would increase, thereby increasing the fuel consumption and the life cycle cost of this option. Table 4 summarizes costs for this option.

### *New LTHW System and Cascades with Existing Boilers*

This scenario assumes that the entire steam distribution system will be replaced with a shallow trench LTHW distribution system.

Table 4. HEATMAP data for new steam system at Fort Campbell.

Peak Building Load (MBtu/hr)	52.1
Annual Building Load (MBtu/yr)	97,940
Peak Plant Steam Load (MBtu/hr)	55.7
Annual Plant Fuel (MBtu/yr)	155,995
Annual Operating Cost (\$)	\$ 721,000
Distribution System Cost (\$)	\$ 5,961,000
20 yr LCC Fuel Cost @\$3.31/MBtu (97 \$)	\$ 9,243,000
Net PW@ \$3.31/MBtu (97 \$)	\$ 16,498,000

### Calculation of Capital Costs

The cost of cascades for converting steam to LTHW (\$300,000) was included in the life cycle cost of this option as a plant retrofit cost. The retrofit cost for converting the buildings served by the system (\$1,300,000) is the same as in other options.

### Estimation of Operation and Maintenance Costs

The maintenance cost was assumed to be the equivalent of one FTE (\$30,000). This maintenance cost is included for the entire study period. If the system is not maintained properly, the thermal losses would increase, thereby increasing the fuel consumption and the life cycle cost of this option.

### Estimation of Future Replacement Costs

Since the life expectancy of a shallow trench steam system is approximately 40 years, no large scale failures would be expected to appear during the study period.

### Estimation of System Heat Loss

The system loss for the distribution system is assumed to be 2 MBtu/hr for the entire study period, since the system is being replaced by a shallow trench LTHW distribution system. The effect of the system loss is felt throughout the season. At part load conditions, the system loss will be approximately 20 percent less than during peak load conditions if a temperature reset control is used. Table 5 summarizes costs for this option.

### *New LTHW System with New LTHW Generators*

In this scenario, it is assumed that the entire steam distribution system will be replaced with a shallow trench LTHW distribution system.

**Table 5. HEATMAP data for new LTHW system with existing boilers at Fort Campbell.**

Peak Building Load (MBtu/hr)	52.1
Annual Building Load (MBtu/yr)	97,940
Peak Plant Load (MBtu/hr)	54.1
Annual Plant Fuel (MBtu/yr)	142,543
Annual Operating Cost (\$)	\$ 663,589
Distribution System Cost (\$)	\$ 6,354,100
20 yr LCC Fuel Cost @\$3.31/MBtu (97 \$)	\$ 8,446,000
Net PW@ \$3.31/MBtu (97 \$)	\$ 17,101,000

### Calculation of Capital Costs

The cost of new LTHW generators for this option (\$1,200,000) was included in the life cycle cost of this option as a plant retrofit cost. The retrofit cost for converting the buildings served by the system (\$1,300,000) is the same as in other options.

### Estimation of Operation and Maintenance Costs

The maintenance cost was assumed to be the equivalent of one FTE (\$30,000). This maintenance cost is included for the entire study period. If the system is not maintained properly, the thermal losses would increase, increasing the fuel consumption and the life cycle cost of this option.

### Estimation of Future Replacement Costs

Since the life expectancy of a shallow trench steam system is approximately 40 years, no large scale failures would be expected to appear during the study period.

### Estimation of System Heat Loss

The system loss for the distribution system is assumed to be 2 MBtu/hr for the entire study period, since the system is being replaced by a shallow trench LTHW distribution system. The effect of the system loss is felt throughout the season. At part load conditions, the system loss will be approximately 20 percent less than during peak load conditions if a temperature reset control is used. Table 6 summarizes costs for this option.

**Table 6. HEATMAP data for new LTHW system with new boilers at Fort Campbell.**

Peak Building Load (MBtu/hr)	52.1
Annual Building Load (MBtu/yr)	97,940
Peak Plant Steam Load (MBtu/hr)	54.1
Annual Plant Fuel (MBtu/yr)	139,108
Annual Operating Cost (\$)	\$ 562,219
Distribution System Cost (\$)	\$ 6,354,100
20 yr LCC Fuel Cost @\$3.31/MBtu (97 \$)	\$ 8,242,000
Net PW@ \$3.31/MBtu (97 \$)	\$ 16,612,000

## Summary for Fort Campbell Study

A new shallow trench LTHW distribution system using a loop around each barracks complex would provide the lowest annual operation and maintenance costs and the lowest annual fuel consumption. The shallow trench LTHW distribution system will cost approximately \$6.5 million. The piping cost estimates used were for a HTHW system and are most likely high enough to include the design and contingency costs for a LTHW system. Therefore a built-in contingency is already included in the estimate for the distribution system. Table 7 lists data supporting a comparison of the life cycle costs.

Table 7. Life cycle cost comparison of alternatives for Fort Campbell.

(All PW Values are in 1000's of 1997 \$)	Existing Steam	New Steam	LTHW Cascade	LTHW New Boilers
Capital Cost PW	0	5,650	7,539	8,392
O&M PW	8,657	2,587	2,424	1,286
Salvage Value PW		-982	-1,308	-1,308
Fuel PW @ \$3.31/MBtu	13,741	9,243	8,446	8,242
Net PW @ \$3.31/MBtu	22,398	16,498	17,101	16,612
SIR @ \$3.31/MBtu	—	2.3	1.9	1.8
DPP @ \$3.31/MBtu	—	9	11	11
Fuel PW @ \$4.71/MBtu	19,553	13,152	12,018	11,728
Net PW @ \$4.71/MBtu	28,210	20,407	20,673	20,098
SIR @ \$4.71/MBtu	—	2.7	2.2	2.1
DPP @ \$4.71/MBtu	—	8	9	9

Even though the new steam system has the highest savings-to-investment ratio (SIR) and lowest discounted payback period (DPP), without proper maintenance it could quickly deteriorate to a condition that would consume up to 25 percent more fuel annually, primarily due to condensate return line and steam trap failure. LTHW systems do not produce corrosive condensate and do not use steam traps, thus they are more likely to provide thermal energy efficiently throughout the economic life of the system.

## 7 Fort Riley Analysis

### Site Survey

The Utilities Modernization Program Support Team conducted a site survey at Fort Riley, KS, on 1-2 September 1998. The team reviewed the design submittals for the Barracks Upgrade Program (BUP), reviewed the alternatives for the proposed CEP modernization project, and toured the central plant and several buildings.

#### *Design Submittals for Barracks Upgrade Program*

The team reviewed design submittals for the BUP. The project includes boiler room expansions and renovations for all of the barracks. At the time of the site visit, the BUP design contract was scheduled to be awarded by 30 September 1998 and work is scheduled to begin in FY99.

#### *Alternatives for CEP Modernization Project*

Fort Riley DPW personnel briefed the team on the alternatives considered for the proposed CEP modernization project for the 8000 area of Custer Hill. The 8000 area of Custer Hill consists of 30 buildings including barracks, company headquarters, battalion headquarters, a mess hall, gymnasium, detached day rooms, and training centers. Total building area is over 400,000 sq ft. The facilities were constructed in the mid-1970s. The 12 barracks in the area are included in the BUP described above.

All heating and cooling in the area is provided by a central plant located in Bldg 8073. The plant houses two high pressure steam natural gas fired boilers at 16 MBtu/hr (500 HP) each, and two single-effect steam absorption chillers at 440 tons each. This equipment is original and nearing the end of its predicted service life.

High pressure steam is distributed to the buildings year round to produce DHW in the barracks, mess hall, and gymnasium. Winter heating is provided using steam to hot water converters located in all buildings. The steam distribution system consists of about 8000 linear feet of piping, of which approximately half is

in shallow trench, and the remainder is direct buried. The shallow trench portion was constructed in 1990. The remaining direct buried portion is original construction and is in poor condition. During the summer, chilled water is distributed to all buildings. The chilled water distribution system is direct buried and in good condition.

According to Fort Riley DPW personnel, several options were studied for heating and cooling system modernization. The plans for the cooling system are the same for all of the options and include: (1) replacement of the absorption chillers with high efficiency electric units and (2) use of the existing chilled water distribution system. DPW personnel briefly outlined the different heating system options:

#### Option A

In Option A, the existing steam system would be converted to LTHW. All boilers would be housed in the existing plant (Building 8073). Existing steam distribution lines in shallow trench would be reused when the size was sufficient. The direct buried portion of the system would be replaced with shallow trench piping. LTHW would be provided year round and used by instantaneous hot water heaters in the barracks, mess hall, and the gymnasium. Other buildings would have no DHW, or would use small gas or electric units. The LTHW system would provide heating in the winter.

#### Option B

Option B is identical to Option A except that gas lines would be run to the buildings using instantaneous DHW heaters. By replacing the instantaneous heaters with gas, the boiler and distribution sizes could be significantly reduced. The LTHW system would only operate during the heating system as DHW is produced by individual gas heaters.

#### Option C

Option C splits the heat distribution system into two loops. An additional plant building would be constructed in the middle of the 8000 area. By splitting the system, the existing shallow trench steam lines would be large enough to be used for LTHW. The existing direct buried lines, along with any new lines, would be placed in a shallow trench. The LTHW systems would operate year round to provide DHW.



### Option D

This option eliminates the central heating system. Natural gas lines would be installed to all buildings. Each building would have its own boiler or furnace for heating. Buildings requiring DHW would have a gas heater. The existing mechanical rooms in the barracks are not large enough for this equipment. However, the BUP design calls for the expansion of the mechanical room into an existing sleeping room. This requires moving a wall and maintaining the required fire rating. The cost estimate for Option D includes the cost of the mechanical room expansion in the event the UMP project precedes the BUP renovations.

### Option E

This option is identical to Option A, except that, in this option, storage type DHW systems are used in the barracks, mess hall, and gymnasium. By replacing the existing instantaneous DHW heaters, the boiler and distribution line sizes can be greatly reduced. The LTHW system would only operate during the heating season.

### Summary and Comparison of Options

Table 8 summarizes Fort Riley's estimates of the nonenergy costs for each option. The construction cost estimates were developed by the A/E under contract to provide design services. The costs *do not* include 6 percent supervision, inspection, and overhead (SIOH) and 6 percent contingency funds.

Since Option D has a lower life cycle cost than the other options due to the much lower construction costs, Fort Riley was chosen to proceed with the design of Option D.

Table 8. Non-energy costs of options for Fort Riley.

Option	Construction: Heating System	Construction: Cooling System	Construction: Total	Annual Maintenance
A	\$4,380,124	\$829,875	\$5,209,999	\$98,000/ yr
B	\$3,833,138	\$829,875	\$4,663,013	\$120,000/ yr
C	\$3,816,056	\$829,875	\$4,645,931	\$110,000/ yr
D	\$2,129,323	\$829,875	\$2,959,198	\$133,000/ yr
E	\$3,175,956	\$829,875	\$4,005,831	\$98,000/ yr

### ***Tour of Plants and Buildings***

O&M personnel from the Public Works Division provided the team with a tour of the Central Heating Plant (Building 8073) and a tour of the mechanical rooms at the following barracks: Building 8042 (568th Engineer Co.); and Building 8040 (24th Transportation Co., 541st Maintenance Bn.).

Building 8073 currently has two, high-pressure steam, natural gas-fired boilers at 16 MBtu/hr (500 HP) each, and two single-effect Trane steam absorption chillers at 440 tons each. A new Johnson METASYS™ System is scheduled to be used for monitoring the boilers and chillers from the Central Plant. The door frame of the Building 8042 mechanical room needs to be replaced because it is corroded. The team also viewed a concrete shallow trench that contains a condensate leak.

### **Energy Screening Analysis**

The CERL-developed energy screening tool discussed previously was used to develop cost curves for different heating systems based on previous DoD plant studies, Redbook data, and utility bills from Fort Riley (Figure 7). The energy density of the entire cantonment area is about 0.260 MBtu/hr/acre. The analysis supports Fort Riley's proposal to go to a decentralized system.

### **Conclusions and Recommendations from Site Visit**

The team gave the following recommendations to the Fort Riley DPW:

1. The project, as proposed by the installation, was validated as being the most life cycle cost-effective. It was emphasized that Kansas City District should proceed to complete design of the project to ensure award within FY99.
2. The team recommended that a revised DD1391 be prepared. One particularly important item was the need for improved documentation of maintenance costs. This is needed prior to the AAA audit.
3. The contract scope of work will need to specify what to do with the boilers in the central plant, including the need for asbestos abatement. Fort Riley will need to manage this aggressively.
4. It was recommended that system commissioning should be put into the contract scope of work.

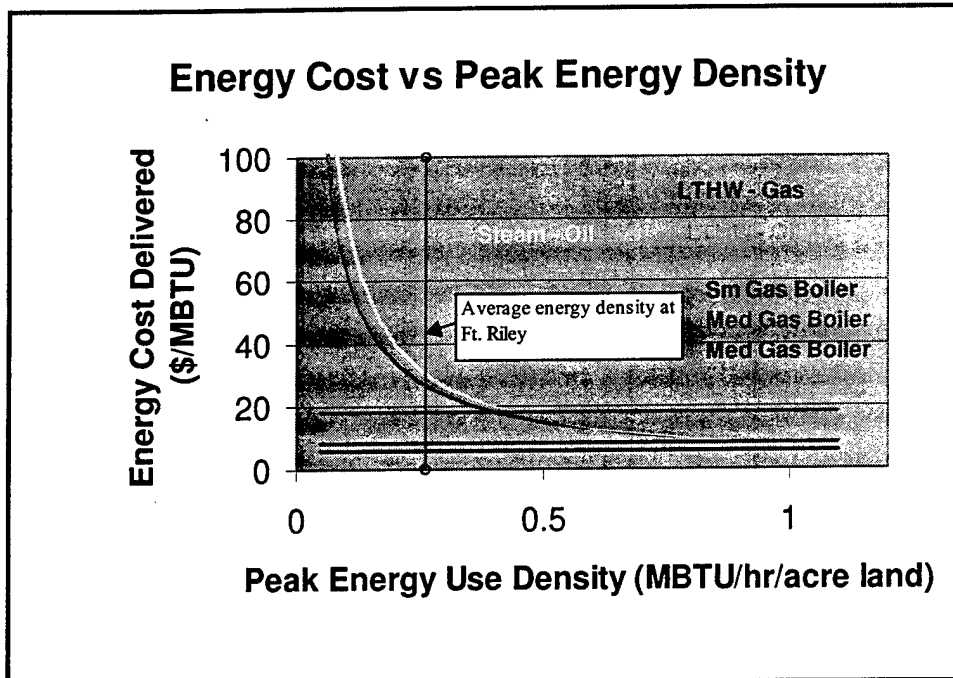


Figure 7. Energy density data for Fort Riley.

## 8 General Procedures and Resources for Analyzing CHP Upgrade Alternatives

This chapter contains some general procedures and information to help installation DPWs formulate and analyze CHP modernization alternatives. These procedures have been developed based on research, Army and Corps of Engineers guidance, and experience with the FY98 Modernization Program. Each installation's needs are different, therefore this chapter should be viewed as general guidance.

### Assess the Existing System

The first step in developing a modernization program is to assess the existing system to determine its condition, identify deficiencies, and determine whether retrofits are needed.

#### *Inventory of Existing System*

An inventory of the existing system should be established before beginning a modernization project. System components (such as pipes, pumps, boilers, etc.) should be identified and basic physical information (such as location, material, and date of construction, size, etc.) should be obtained. Good sources of information include distribution system maps, as-built drawings, plant schematics, machinery records, and other similar documents. These documents should be collected, reviewed, and organized. This information will be used in the analysis of CHP modernization alternatives and will also be valuable to the design engineer for planning the modification or demolition of existing equipment.

The HEATER and HEATMAP programs provide guidelines and a structured framework for obtaining and organizing inventory data. The HEATMAP program was described previously. The HEATER EMS is designed to help installations with inventory, condition assessment, condition prediction, and cost-effective M&R planning for heat distribution systems. It is similar to PAVER, ROOFER, and other CERL-developed EMSs. HEATER is scheduled for Army-wide release in late FY99; however, some program modules are currently

available for beta testing and use. CERL and CEISC can provide assistance with the implementation of the HEATMAP and HEATER programs.

### ***Review of Maintenance Records***

Distribution system and plant maintenance records should be reviewed to pinpoint areas of high maintenance, recurring problems, or frequent customer complaints. Such areas are likely to be excellent candidates for modernization. For example, a branch of the distribution system with an unusually high number of leaks may require replacement.

Plant and distribution system maintenance personnel should be interviewed during this phase to obtain their input on problem areas. Experienced personnel who have witnessed the deterioration of the system over a period of years are a particularly valuable source of information.

The information obtained from maintenance records and personnel should be used as a guideline for the physical inspection. This is especially important if not enough resources are available to perform a complete survey of the entire plant and distribution system.

### ***Review of Boiler Plant Logs***

The boiler plant logs and records provide quantitative information on the performance of the existing heat system. The data from the logs can be used to analyze the building load, boiler performance, and the system losses.

Totals and averages from the monthly logs (DA Form 3967 or similar) should be plotted and reviewed to estimate current and projected annual energy consumption. The totals can be correlated to the historical weather data over the time period by plotting the plant energy supply (fuel consumed or steam output) against outside air temperature. Figure 6 shows this plot for Fort Campbell. System losses and building loads can be determined from the plot, as described in Chapter 6.

The boiler logs will reveal the load points that characterize the system. The following loads should be identified:

- The coldest working day peak 5-minute load
- The coldest day hourly load
- The hottest holiday hourly load
- A spring/autumn day peak hourly load.

If possible, a load duration curve should be developed from the logs. Sample load duration curves are available in TM 5-810-15.

Another valuable correlation is the flue gas temperature versus boiler load. In general, a rising flue gas temperature over time indicates problems in the boiler.

The makeup rate can be obtained from the boiler logs and can provide a clue on the condition of the distribution system. If the makeup rates are excessively high and/or are increasing significantly over time, it is likely that there is a problem in the distribution system. There could be leaks in the supply or return piping, or in the building equipment at the point of end use. In a steam system, high makeup rates can also indicate that condensate is being "dumped" instead of being returned to the boiler plant.

The makeup rate and a model of the heat transfer losses for a correctly operating system can be used to estimate the thermal losses due to failures in the distribution system.

The boiler water chemistry logs should be reviewed to determine if the boiler water and condensate chemistry are within the Army-recommended ranges as explained in TM 5-650. The water chemistry logs should also contain information on treatment chemical usage. Total costs of chemical treatment can be calculated from the usage data and the unit cost of the chemical.

### ***Boiler Plant Inspection***

The existing boiler inspection reports should be reviewed first. The annual inspection is usually limited to certifying pressure vessel integrity. Therefore, a more comprehensive inspection should be conducted to determine the condition of the fuel train, burner (or grate), and furnace. A typical list of heating plant items to inspect are:

- coal and fuel oil handling systems
- burner management systems
- pneumatic and electronic controls
- combustion air flow systems
- boilers
- mechanical (multi-cyclone) dust collectors (MDC) (coal)
- electrostatic precipitators (ESP) or Baghouses (coal)
- pneumatic ash handling system (coal)
- hot water distribution, steam distribution, and condensate return system, including piping, valves, and converters
- water treatment systems.

Inspection techniques for boiler plant assessment include ultrasonic testing (UT), eddy current testing, ash mineral analysis, boroscope, flue gas analysis, and metallurgical analysis. CEISC or CERL can provide boiler inspection support, either directly or by referring the installation to a government or commercial boiler inspector.

### ***Boiler Plant Performance Testing***

Performance (efficiency) testing for coal, oil, and gas-fired steam boilers and HTHW units should be conducted according to the procedures in the ASME Power Test Code 4.1 (ASME PTC 4.1). The heat transfer efficiency of the steam generation unit is tested either by measuring the input and output, or by measuring the unit heat loss. ASME PTC 4.1 suggests that the unit be tested at a minimum of four load points. The test runs for oil and gas should be 4 hours long. Coal stoker test runs should be at least 10 hours long, preferably 24 hours long. A full ASME PTC 4.1 test can take several days for one boiler. However, abbreviated runs can provide enough data to estimate the unit's efficiency.

Performance tests of other auxiliary components should be conducted. Test and inspection procedures for individual coal boiler pollution control system components such as MDC leak checks and ESP plate alignment checks can be obtained from CERL. If a complete U.S. Environmental Protection Agency (USEPA) emissions test is desired, the U.S. Army Center for Health Promotion and Preventative Medicine, Air Programs in Aberdeen, MD, can provide that service on a reimbursable basis.

### ***Distribution System Inspection***

Inspection of the distribution system should include pipes and manholes. Procedures for inspecting pipes and manholes have been outlined in previous publications (Demetroulis, Hock, and Segan 1991; Marsh, Demetroulis, and Carnahan 1996). CERL is incorporating these procedures into the HEATER EMS described previously.

Aboveground piping is usually inspected visually. Buried piping may be assessed by infrared thermography, pressure testing, and/or excavation.

Manholes and the equipment inside them are usually inspected visually. Many older manholes contain asbestos and will require special inspection procedures (Demetroulis, Hock, and Segan 1991).

Measurements should be taken at remote points of the distribution system for correlation with the expected design values or for validation of system performance models generated by a tool such as HEATMAP. Pressures should be measured for steam systems and temperatures should be measured for hot water systems. CERL and CRREL can provide assistance in inspecting heat distribution pipes and manholes.

## **Identify Candidate Energy Supply Options**

In general, energy supply alternatives should be identified by starting with those with the greatest savings potential based on the utility costs. It is a good idea to keep a mix of energy sources to reduce dependence on any particular fuel. Use of dual fuel components should be considered to improve energy supply security. If #2 oil is used as a backup to natural gas, it is important to be aware that oil prices and availability are closely coupled to natural gas price and availability.

All possible energy sources should be identified and their current rate structures should be obtained from the local utilities. Natural gas, propane, coal, fuel oil, and electricity are available at most sites. Any applicable rebate programs or other incentives that could lower costs should be investigated. If possible, alternatives such as wind, solar, and geothermal energy should be considered. Use of waste energy (typically heat from engines or chillers) may also be a viable option.

The Army Power Procurement Directorate and DESC offer fuel and energy contract services. They can provide energy contract price information and can negotiate new energy supply contracts on behalf of installations.

## **Examine Centralized vs. Decentralized System Options**

Many of the existing Army central heating plants were constructed in the 1940s and 1950s. The prevailing plant design relied on low cost solid fuel (coal), a large well trained labor pool, and few pollution control systems.

With the growth of the gas industry and increase in emission control requirements, gas-fired boilers have replaced most of the coal-fired systems. Central gas-fired boilers still offer the possibility of dual fueled systems because most of these systems can be ordered with oil and gas burners.

Some installations are now abandoning their central plants in favor of small unattended gas boilers, water heaters, and furnaces that are installed at the



individual buildings. The higher costs of uninterruptible natural gas (30 to 40 percent price premium) can often be offset by the reduction in skilled labor costs and elimination of distribution system losses.

The following sections describe the many factors that must be considered when choosing between a central and a decentralized system.

### ***Thermal Factors***

The "energy use density" should be considered when deciding whether a centralized or decentralized system is most favorable. The problem is solved by correctly balancing the losses of moving the steam and hot water through the distribution system against the inefficiencies of oversized or cycling decentralized conversion equipment. Marketing and feasibility studies in North America and northern Europe have shown that high peak energy use density (MBtu/hr/acre) and high load factor are important factors for ensuring profitable district heating plant projects (Bloomquist, Nimmons, and Rafferty 1987). It is reported that district heating plants are generally favorable at densities greater than 0.7 MBtu/hr/acre, possible at 0.28 to 0.7 MBtu/hr/acre and unfavorable or questionable at less than 0.28 MBtu/hr/acre.

The energy screening tool that was used in the Fort Eustis, Fort Carson, and Fort Riley analyses described previously is an excellent tool for determining energy use density. The tool is quick and easy to use and helps evaluate the favorability of central plants using either Redbook or installation-supplied data. CERL developed the tool and can provide further information on its availability and use.

### ***Economic Factors for Central Plants***

The following sections discuss several economic issues that need to be considered for central plants.

#### ***High Maintenance/Low Reliability***

Many DoD CHP boilers are 30 or more years old and are pushing performance limits. Older, less reliable boilers have higher maintenance costs and increased potential for failure, creating a more urgent need to consider either construction of a new boiler unit or modernization of the existing unit.

### **High Cost of Capital to Build New Unit**

Costs of complying with environmental, siting, and safety regulations add to the construction cost of new CHP units. Modernization programs have the potential advantage of lowering the capital investment since existing units can be retrofitted and upgraded.

### **Poor Performance of Existing CHP**

Systems may need to be optimized. Incorporating advances in boiler system design may become a cost-effective means to improve system performance.

### **Distribution System Maintenance**

The steam and condensate system requires an aggressive maintenance program and a reliable water treatment system.

### **Three-Shift Operating Staff**

Depending on the jurisdiction, attendance is required above certain boiler sizes (usually industrial boiler sizes). The jurisdiction may require at least two personnel in a boiler plant if it is considered a hazardous materials space. A staff of 10 to 13 operating personnel may be needed just to meet attendance and safety regulations.

### ***Economic Factors for Decentralized Systems***

The following sections discuss issues that must be considered for decentralized systems.

#### **Boiler Safety Equipment Maintenance**

Every boiler will have at least one safety valve and fuel train requiring maintenance. Maintenance on the safety system cannot be deferred. There is a fixed amount of maintenance required on a commercial or industrial boiler regardless of its size.

#### **Firm Gas Price Fluctuations**

Smaller boilers will only be fueled with gas. Firm (uninterruptible) priced gas will cost 30 to 40 percent more than the locally available interruptible gas supply.

### **Contractor Support**

In most areas, there will be a larger pool of contractors qualified to operate and maintain smaller commercial-sized boilers than larger industrial-sized boilers.

### ***Policy Factors***

Several policy issues set the framework for energy supply in addition to thermal and economic factors. Regulatory, fuel security, and program funding issues frequently impact the feasibility of modernization or decentralization.

### **Environmental Regulations**

Regulatory forces may have two types of impacts on an existing CHP: (1) regulations may require an upgrade of the CHP, or (2) regulations may make decentralization preferable to upgrading or building a CHP. Regulations that affect CHP operation include environmental regulations, siting clearances for new units, and safety code regulations.

Environmental regulations include the amended Clean Air Act (CAA), which applies more stringent emissions limits on particulate matter, sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), carbon monoxide (CO), air toxins, and volatile organic compounds (VOCs). Additionally, the CAA calls for the complete phaseout of chlorinated fluorocarbons (CFCs) and certain other stratospheric ozone depleting substances. CHP combustion produces SO<sub>2</sub> and NO<sub>x</sub> in amounts that vary with fuel type. Since natural gas is the primary fuel used in many DoD installations, NO<sub>x</sub> emission is the primary pollutant.

Utilities, industry, and the military face the same regulatory forces. The differences lie in the magnitude of pollution potential and in the ease of obtaining siting clearances. Utility fossil-fired plants tend to have higher annual fuel input than industrial or military plants, which may lead to more concern about pollution at utility plants. New utility projects require new site clearances that require action from several regulatory bodies. Industrial and military projects tend to be on sites under their respective control.

### **Energy Legislation**

The Energy Policy Act of 1992 (Public Law [PL] 102-486) Subtitle F, Federal Agency Energy Management, establishes several Federal agency goals and requirements. It amends sections of the National Energy Conservation Policy Act to reflect and supplement goals and requirements established in Executive Order

12759, Federal Energy Management. It contains provisions regarding energy management requirements, life-cycle cost methodology, budget treatment for energy conservation measures, incentives for Federal agencies, reporting requirements, new technology demonstrations, and agency surveys of energy savings potential. The DoD establishes guidelines for meeting Federal energy goals with Defense Energy Program Policy Memorandums (DEPPM) such as DEPPM 91-2, *Implementing Defense Energy Management Goals*. The Army issues memorandums to support the DoD goals.

### **Fuel Security**

Central heating plants provide the opportunity to fire multiple fuels. If a burner conversion or upgrade is needed, it is easier to modify a few boilers at a central plant than dozens of small boilers throughout the system. If oil capability is needed to augment natural gas, it is easier to manage a few centrally located oil storage tanks than a large number of small tanks. Small decentralized boilers are almost always gas fired. There may be a few electric boilers to provide point of use hot water or steam. These small gas boilers will need to be provided uninterruptible gas unless the site can permit the space to be unheated. As mentioned earlier, the price premium for firm (uninterruptible) gas is 30 to 40 percent above the available interruptible gas price. Firm gas prices may vary as much as \$2/MBtu over the course of a year (Energy Information Agency [EIA] 1998). Base managers therefore need to account for the price risk when analyzing the feasibility of decentralizing or modernizing a central heating plant.

### **Base Realignment and Closure (BRAC)**

BRAC may impact the CHP modernization options because realignments may add or remove activities from an installation. This will ultimately change the installation's energy demands.

### **Privatization**

AR 420-49 has been revised and requires life cycle cost analysis and comparison of Army-owned heating plants and systems with private and municipal alternatives. Additionally, the Defense Reform Initiative (DRI 1997) states that:

By January 1, 2000, the Department will privatize all utility systems (electric, water, waste water and natural gas) except those needed for unique security reasons or when privatization is uneconomical.

Although boiler plants are not listed in the DRI, it can be inferred that if economical and feasible, privatizing thermal utilities would support the intent of the DRI, which is to divest the DoD of activities not directly related to the core function of the services, that being to wage a war.

## Identify Heating Medium Options

### *Steam*

Army steam heating boilers typically operate to provide 5 to 125 psig steam. Since the vast majority of Army boilers do not provide steam for electrical generators, they are classified as industrial boilers. The smaller boilers installed in individual buildings would be classified as commercial boilers. The ASME boiler code classifies boilers according to pressure. ASME classifies units below 15 psig as heating boilers. ASME heating boilers may be constructed out of cast iron or steel and have less restrictive material and construction requirements. However, an improperly operated and maintained heating boiler can kill personnel and severely damage equipment. Above 15 psig, ASME classifies these units as "power boilers." Power boilers can only be constructed of steel and have more stringent design and construction criteria.

Steam systems have several advantages over hot water systems. Steam is required for some industrial processes on Army installations, and it is well suited for many munitions processes that require heating without flames or combustion. Steam systems have lower pumping power requirements than hot water systems. Motive force to return the condensate can be provided by gravity if manhole locations and pipe depths are selected wisely.

Steam systems have several disadvantages. First, there is a significant safety issue. DoD steam distribution system failures have been responsible for several serious injuries and deaths. Entry into steam system manholes requires the use of confined space procedures. Second, steam systems have a much higher makeup rate than hot water systems. Greater attention to the water treatment program is required for steam systems; poor water treatment can significantly shorten the service life of the boiler, and can result in corrosion problems in the condensate return system. Finally, steam systems require an aggressive maintenance program, especially for steam traps. A steam trap life span is only 2 to 5 years depending on its type and location in the system. More time is needed for a steam system than for a low or medium temperature hot water system to cool down and depressurize before maintenance is performed.

## ***Hot Water***

The ASME boiler code classifies hot water units as low pressure heating units and high pressure power units. Hot water generators below 60 psig and 250 °F are allowed to be constructed and designed with materials and methods used for heating boilers. If a unit exceeds either 60 psig or 250 °F, power boiler (section I) requirements apply. AR 420-49 does not specify temperature classifications, but requires only inspection of hot water units operating above 250 °F. The National Model Boiler and Pressure Vessel Code suggests an inspection frequency of 12 months for high pressure units and 24 months for low pressure units. However, the implementation of the code as law is a state prerogative. Each state will have its own inspection requirements. CERL has access to a synopsis of all the state requirements available from the Uniform Boiler and Pressure Vessel Laws Society, Inc. (UBPVLS) and can provide assistance in ascertaining local requirements.

Package hot water generators are similar in cost, construction, and size to boilers having the same heat input. Larger field-erected hot water units are designed with smaller tubes and with special tube headers and tube orifices to ensure a uniform water supply to each tube. In the larger units, reduced water flow in a tube can result in tube rupture.

Hot water distribution systems are functionally classified as low temperature (below 200 °F), medium temperature (250 to 330 °F) and high temperature (350 to 455 °F). Thermal losses in the distribution system are reduced as the temperature of the hot water is reduced.

Hot water distribution systems generally require less maintenance than steam systems. For example, there are no steam traps to maintain in a hot water system. Low or medium temperature hot water systems require less time than steam or HTHW systems to cool down and depressurize before maintenance is performed. There are fewer safety issues with hot water systems than with steam systems. Also, hot water systems have high thermal inertia, which means that the large volume of water in the system acts like a heat reservoir between the plant and the end user.

On the downside, the hot water system requires more pumping power than a steam system. Larger pipe diameters may be required as the temperature is reduced, thereby increasing the capital cost. Operators and designers need an increased understanding of hydraulics and may require additional training.

## Identify Options for Distribution System Type

### *Regulations and Guidance*

AR 420-49 dictates the Army requirements for usage of various types of heat distribution systems. The regulation states that:

Heat distribution systems for 201 °F and above will be designed in accordance with TM 5-653 and TM 5-810-17 and will be selected in the order of preference: 1. Above ground, 2. Shallow concrete trench, 3. Direct buried. Direct buried systems will only be used where aesthetics or functional requirements preclude the use of above ground or shallow trench systems.

The following Corps of Engineers Guide Specifications (CEGS) give design and construction guidance for the various types of distribution systems:

CEGS 02552: *Pre-Engineered Underground Heat Distribution System*

CEGS 02553: *Heat Distribution Systems in Concrete Trenches*

CEGS 02554: *Aboveground Heat Distribution System*

CEGS 02555: *Pre-Fabricated Underground Heating/Cooling Distribution System.*

### *Aboveground Systems*

Aboveground distribution systems have the lowest installation cost and lowest maintenance costs of any distribution system. This system is a good choice for industrial areas and for areas where water tables are high. Many installations resist installing aboveground systems since the exposed piping and supports are not visually appealing. Thoughtful system routing and landscaping can help overcome this problem.

The two most common types of aboveground distribution systems are low profile and high profile. The bottoms of the pipes are mounted no more than 4 ft above grade except at road crossings, which usually incorporate high profile supports or an underground section. High profile systems are routed 14 to 16 ft above grade to cross roads and avoid obstructions (TM 5-810-17, 1994).

### *Concrete Trench Systems*

The concrete shallow trench (CST) is a system that allows insulated carrier pipes to be routed underground without placing the piping in contact with the soil. The system also provides comparatively easy access for maintenance and repair by means of removable concrete tops. The exposed trench tops have been used as sidewalks. However, the sidewalk locations and elevations are usually poor

routes for the distribution system, pedestrian traffic will be interrupted during maintenance, and system components (such as lifting connections, lid sealing material, and lid joints) may present a trip hazard. It is sometimes advantageous to cover the CST with soil formed in a low berm as long as the grading design will ensure that ground water will not pond or sit over the trench for any length of time. The trench should not be routed through existing flood plains, swales, or in areas where seasonal water accumulates. In areas where seasonal ground water will cause a trench flotation problem, the design will include a subdrainage system along the trench.

### ***Direct Buried Systems***

Unlike concrete shallow trench systems, which are totally designed by the project engineer, pre-approved direct buried systems are designed by the system manufacturer and preapproved by the Federal Agency Committee for Heat Distribution Systems. Proof of system compliance with the preapproved requirements is a product brochure for the direct buried system, which includes a Federal Agency Letter of Acceptability. The approved brochure is a required contract submittal. These preapproved systems are factory fabricated in lengths that are transported to the site for field assembly.

The systems are separated into four site classifications from "A" to "D," where "A" designates the most severe conditions. Manufacturers are to install their systems only in the site class for which they are approved in the Federal Agency Letter of Acceptability (TM 5-810-17, 1994).

## **Formulate Viable Alternatives**

Based on the findings of the condition assessment and the review of potential technologies as described in the first part of this chapter, alternatives can be formulated for detailed analysis. In the early stage of analysis, it is best to be creative in configuring scenarios to ensure that all opportunities for savings are investigated.

## **Analyze the Alternatives**

A description of the general procedure for analysis of CHP alternatives is presented in the following paragraphs. The Fort Campbell case study in Chapter 6 is a good example of the process. The reader may wish to refer back to it while reviewing this section.



### ***Evaluate the Status Quo***

Analysis of alternatives should begin with an evaluation of the existing system, or "status quo." The analysis period is generally 25 years.

### **Predict Remaining Component Life**

The remaining useful life of the existing equipment should be predicted. This is especially important for the most costly components such as the piping and boilers. The current condition (as observed during the inspection) should be used as a starting point. The remaining life can be estimated in several ways, depending on the available information.

One method involves the use of predictive models that take into account the installation-specific conditions such as soil and water chemistry. This method was demonstrated in the Fort Drum case study (Chapter 5). Predictive capabilities are currently being incorporated into the HEATER program.

Another method is to review service life data or repair records for similar equipment at the installation of interest. For example, DPW repair records might show that a specific type of piping has an average service life of 18 years at that particular installation.

### **Estimate Repair Costs for System Deficiencies**

Repair estimates should be developed for the system deficiencies that were observed in the inspection. The life span of the repaired system should also be estimated.

### **Estimate Future Replacement Costs**

The replacement cost should be estimated for all equipment that will reach the end of its life cycle during the life cycle analysis time frame.

### **Estimate O&M Costs**

O&M costs should be determined for the repaired existing system. This will include both labor and materials.

To determine the labor cost for system operation, a copy of prevailing wage rates for the location of the plant and/or the installation's Wage Grade pay schedule should be obtained. The number and classification(s) of employees required for

operation and maintenance of the system should be determined and the annual cost should be calculated. It is a good idea to obtain cost estimates for system operation and maintenance from third parties or to compare requirements with similar plants at other DoD installations.

To estimate the maintenance and repair cost, the past 3 to 5 years of installation M&R cost records and data should be reviewed. If the local records are incomplete, an estimate can be obtained by reviewing K account expenditures as reported in the Redbook.

### **Estimate Annual Fuel Consumption Costs**

Annual fuel consumption costs can be estimated from the boiler logs (Chapter 6).

### **Construct and Validate the Status Quo HEATMAP Model**

An accurate HEATMAP model of the existing heat distribution system is an inexpensive, yet valuable tool for analyzing CHP modernization alternatives. DPW engineers can use the HEATMAP model to do the following for almost any proposed scenario:

- Optimize pipe sizes
- Calculate capital costs
- Estimate energy costs
- Estimate system heat losses
- Optimize system operation.

The results can then be used in the Life Cycle Cost in Design (LCCID) program (Lawrie et al. 1988) for life cycle cost analysis.

The only information required for a HEATMAP analysis is a map of the distribution system (preferably in electronic format) and building area and usage data. Metered data or other thermal load analysis data should be used for consumer loads when it is available. If actual consumer load data is not available, HEATMAP will estimate the loads from the building area and usage information. Installations may obtain a copy of the HEATMAP program from CERL. CERL can provide assistance with constructing and validating the HEATMAP model and analyzing modernization alternatives on a reimbursable basis. CERL can also provide training for installations that wish to perform the HEATMAP analysis themselves.

The HEATMAP simulation relies on several estimates and assumptions to make calculations about the flow characteristics and thermal performance of the heat distribution system. It is therefore important to use actual steam flow and fuel consumption data from the installation to verify that the simulation results are reasonable. The procedure is shown in the Fort Campbell analysis (Chapter 6).

#### **Perform Life Cycle Cost Calculation for Status Quo**

After the economic and life prediction data have been gathered, a life cycle cost calculation should be performed. The best way to do this is to use the LCCID program or other similar economic analysis tool such as building life cycle cost (BLCC).

#### ***Evaluate the Modernization Alternatives***

##### **Estimate Capital Costs**

The equipment size and capital cost should be calculated for each alternative. For decentralized systems, it is important to understand that the sum of the required peak building loads will be much greater than the sum of the building loads used in a central system evaluation. This is because the central systems can capitalize on load diversity.

For the decentralized option, some buildings will need to have redundant systems depending on the occupant's mission. Building, plant, or other system retrofit costs such as new gas lines, new HVAC equipment, and electrical supply equipment should also be included in the capital cost estimate.

For the central plant options, HEATMAP or CHPECON can be used to calculate central energy plant and distribution system sizes and capital cost. CHPECON is a program developed by CERL that estimates equipment, O&M, fuel consumption, and capital investment for new boiler plants and then calculates the life cycle cost of the proposed new plant (Lin and Kinast 1996).

##### **Estimate Operations and Maintenance Costs**

The annual O&M costs for each alternative should be estimated using component efficiencies and maintenance requirements for the selected equipment. It is important to note and validate the assumptions that are made here to make the audit process more efficient.

### **Estimate Future Replacement Costs**

The replacement cost should be estimated for all equipment expected to reach the end of its life cycle during the life cycle analysis time frame.

### **Estimate System Energy Consumption and Losses**

Building demand profiles can be used to calculate annual energy consumption. Conservative assumptions for energy efficiency should be used in the first screening pass. System energy losses for centralized systems can be estimated using the HEATMAP program.

### **Perform Life Cycle Cost Calculation of Options**

The next step is to compare all reasonable options over the economic life of the equipment, usually 25 years. Sort the alternatives by their life cycle cost. Then, determine the sensitivity of the lowest cost systems to changes in fuel costs. The HEATMAP and LCCID programs can be used for this analysis.

### ***Make the Decision***

The information gained from all of the analyses should be used to decide the best alternative. The life cycle cost is generally the driving factor, but as discussed previously, there are other factors to consider. Environmental, safety, and personnel issues and benefits for each option should be identified and considered even if they cannot be used in the life cycle cost analysis. Be sure to consider the complexity of the equipment and its maintenance requirements to help select the scenario that will work most efficiently and reliably for the installation.

## 9 Tips for Preparing the DD Form 1391

Once the installation DPW has decided on a specific CHP upgrade project, the next step is to prepare a DD Form 1391 describing it. The 1391 is the primary method for installations to transmit information about a proposed modernization project to the agencies in charge of approval and funding. Some of the 1391s that were submitted to the FY98 CHP Modernization program were not approved due to problems with work classification and/or project packaging. These 1391s were returned to the installations for them to revise and resubmit, and projects were delayed by weeks or months.

CEISC has provided the guidance in this chapter to help installations avoid common problems and pitfalls in the preparation of the 1391 for CHP modernization projects.

### Technical Review and Project Approval

According to AR 420-10, paragraph 4-5.f., MACOMs submit two types of Operations and Maintenance, Army (OMA) M&R projects to the Projects Office (CEISC) to be processed for approval by the Department of the Army. They are:

1. All projects over \$2 million
2. Projects that are both over \$500K and over 50 percent of the replacement cost of the Real Property Facility (RPF).

Both types of projects are handled the same way. The only difference is the paragraph used to justify the approval: All M&R projects are approved by the Office of the Assistant Chief of Staff for Installation Management (OACS[IM]), DAIM-FDF-B. (DAIM-FDF-B has no approval authority for construction.) The Projects Office reviews these projects for technical correctness and coordinates the review with other interested offices such as Privatization, Community and Family Support Center, Environmental, and Historic Preservation.

During the technical review, the reviewer verifies that the DD Form 1391 contains all information necessary to obtain approval, that the work is properly classified, and that the work is properly packaged.

Work classification means that different types of work must be clearly separated. The following questions are addressed in the work classification review of M&R projects:

1. Is the project justified as a M&R project by the verbiage?
2. Have the problems with the RPF been identified and components being fixed justified as failed and failing?
3. Does the proposed fix fall under M&R or is it partly construction?
4. Has all new work been identified as a separate project?

The following questions are addressed in the project packaging review:

1. For an associated construction project, is the scope clear and separate from the M&R project and is the cost within local approval levels?
2. Have the funds been identified (OMA; 'K', 'L'; NAF, QOLE, D, private, etc.) and are they appropriate for the intended use?
3. Does the DPW understand that the associated construction project must be locally approved?
4. Does the project appear to be a multi-year funded phased project, and are all phases accounted for in the approval package?

The Projects Office is the technical expert in the Army on work classification. Assistance is provided to installations and MACOMS on project packaging, types of funding for projects, and work classification on specific projects, as requested.

## **Repair vs. Construction When Conversion Takes Place**

### ***Definition of Functional Conversion***

Functional conversion is one of the most difficult areas of work classification. A functional conversion is a requirement that changes the Category Code (CAT CODE) of an RPF. The Army uses five digits to identify facilities. The first three digits are used in work classification to determine a functional conversion. DA Pam 420-11, Paragraph 1-7.j. states:

"For work classification purposes, a Real Property Facility (RPF) is a separate and individual building, structure, utility system, or other real property improvement identifiable in the three-digit Category Codes listed in AR 415-28. Examples are as follows:

- (1) Buildings. One enlisted personnel barracks (Category Code 721) represents a single RPF. A barracks facility damaged by fire may be

repaired if the foundation and walls still exist, and do not require total replacement."

Therefore, an example of a functional conversion is changing the CAT CODE of a building from 72120, Transient UPH, to 61075, Courtroom.

Changes in the last two digits are not considered as a functional conversion. For example, changing CAT CODE, 72120, Transient UPH, to 72170, UPH Senior NCO, is not a functional conversion.

### ***Guidance from DA Pam 420-11***

All of the work needed in a facility that is being converted does not automatically become "construction." DA Pam 420-11, *Project Definition and Work Classification*, addresses conversion in several locations:

Paragraph 2-2.c.(1) Buildings: Work pertaining to the conversion (in the sense of facility modification caused by a change in facility use), addition, expansion, extension, alteration, or total replacement of a building is classified as construction.

Paragraph 2-2.c.(1)(d), Example D: Alterations in arrangement of utilities within buildings, initial permanent installation of equipment, adding doors, windows, for functional reasons is construction. However, in case of conversions, repair work to the facility which would have been done regardless of its functional use and irrespective of the conversion project, is classified as repair.

Paragraph 2-2.b.(1)(m) Example M: During conversion, overlaying an existing, failing vinyl floor with vinyl or carpet as a prime floor finish, in accordance with current criteria, is repair.

Table B-2 of DA Pam 420-11 provides an outline of work classification. The table classifies a project with the following attributes as "Construction":

- existing items or component (buildings, road, roof shingles, electric lines, poles, sewer line, pipe, manhole, etc.)
- not deteriorated by action of elements or wear and tear in use
- work proposed will change functional purpose (change of category code).

### ***Relationship Between Conversion and Repair***

The definition of repair, published by DoD on 10 February 1999 (JP 1-02), does not affect the paragraphs on conversion contained in DA Pam 420-11. In

general, the conversion of a facility does not change the condition of the components of a facility.

If a component was considered failed or failing before the conversion, it is considered failed or failing after the conversion and the component may qualify for repair, for example:

- A roof that is in failing condition needs repair regardless of the use of the facility.
- If the floors in the old use were considered failing, then the floors may be repaired to the same extent as the old use. If the new use requires floors that are more expensive, the difference in costs would be considered construction.

The repair of the component can be performed to the extent that the repair would have been made prior to the conversion (to the codes or standards of the previous use), for example:

- Suppose the old use required a 100-ton HVAC unit and the new use requires a 150-ton HVAC unit. If the increase in size is caused by the conversion (increase in demand) that portion would be considered construction. If the increase in size can be justified by a change in the standards or codes for the original use, the increase may be considered repair.
- Suppose that the doors in a facility are failed or failing. If the old use required a T-30 door, but the new use requires a T-60 door, the difference in costs may be considered construction, as long as the doors were truly failed or failing in the old use.

### ***Work Driven Solely by Conversion***

Any work driven solely by the conversion is construction, for example:

- If the new use dictates specific arrangements of walls, then the work done to reconfigure the walls would be considered construction. Rearrangement of the utilities systems to fit the new wall arrangement would also be construction.
- Demolition of walls to make larger rooms or conference rooms would be construction.
- Any work done on components that are not failed or failing is considered to be construction.
- Work done to bring the facility up to the standards and codes of the new use would be considered construction. (If the new use required the bathrooms to be compliant with the Americans with Disabilities Act, the work done to the bathrooms to make them compliant would be construction.)



## 10 Points of Contact

Installations requiring technical assistance on the topics discussed in this report may contact any of these persons:

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